Lampiran 20

UTM/RMC/F/0024 (1998)

UNIVERSITI TEKNOLOGI MALAYSIA

BORANG PENGESAHAN
LAPORAN AKHIR PENYELIDIKAN

TAJUK PROJEK : **BIOREMEDIATION OF COLOR CONTAMINANT FOR TEXTILE DYEING WASTEWATER USING AEROBIC GRANULAR SLUDGE**

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BIOREMEDIATION OF COLOR CONTAMINANT FOR TEXTILE DYEING WASTEWATER USING AEROBIC GRANULAR SLUDGE

(BIOREMEDI TERHADAP PENCEMARAN WARNA BAGI AIRSISA PERWARNAAN TEXTIL DENGAN MENGGUNAKAN ENAPCEMAR GRANUL AEROBIC)

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2007

Abstract

Degradation process of wastewater through biological treatment approaches offer great advantages over physical and chemical treatment process. Biological treatment using aerobic granular sludge in sequential batch reactor has become a novel application particularly for the treatment of industrial and municipal wastewater. However many factors that are believed to influence the development of aerobic granules are not yet clear especially related to the treatment of textile wastewater. In this study, identified specialised dye degrader microbes was integrated in the development of aerobic granules which will later be used for the treatment of textile wastewater. This study is still in the progress of developing the aerobic granules. This report presents the progress of work that has been conducted up to today.

Abstrak

Proses penguraian air sisa melalui rawatan secara biologi mempunyai keupayaan yang lebih baik berbanding dengan proses rawatan secara fizikal dan kimia. Rawatan biologi menggunakan enapcemar granul aerobik dalam sistem reaktor kelompok berjujukan merupakan applikasi yang baru terutamanya dalam rawatan air sisa industri dan perbandaran. Walau bagaimanapun terdapat banyak faktor yang dipercayai mempengaruhi pembentukan granul aerobic masih lagi tidak jelas terutamanya berkaitan dengan rawatan airsisa tekstil. Dalam kajian ini, mikrob pengurai warna yang telah dikenalpasti akan digunakan dalam pembentukan granul aerobik yang mana kemudiannya akan digunakan dalam rawatan air sisa tektil. Kajian ini masih lagi dalam proses pembentukan granul aerobik. Laporan ini membentangkan kemajuan terkini projek.

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CHAPTER ONE

INTRODUCTION

1.1 Statement of Problems

Textile production is one of the main industrial businesses in most part of the world. It provides huge advantages to economic values as well as social aspect. The world production of textile has reported to reach about 30 million tones annually (Talarposhti et al, 2001). Textile production engaged mainly chemical process, large water consumption particularly in dyeing and production of cloth. One of the main issues here is the large water consumption generating huge amount of textile wastewater. Owing to the nature of the textile industrial processes, which involve the use of different raw or synthetic materials and varieties of chemical in its processes, textile industries have created significant environmental impact. According to Reid (1996), textile industry has been rated as one of the most polluter in the industrial sectors. The textile wastewater was characterized with high concentration of BOD, COD, total organic carbon (TOC), suspended solids, colour (Nigam et al. 1996) and contained high concentration of colouring agent that will deteriorate aesthetic value. Indeed since decades and until now study have focused on treating the textile wastewater by many researches throughout the world in providing the best approaches and solution for textile wastewater treatment.

1.2 Needs of Research

A number of approaches have been used in treating the textile industrial effluent. At present, major methods in textile wastewater treatment involve physical and/or chemical processes. However, such methods are often costly. Some treatments even though may be able to remove the colour but are just transferring one problem to another problem as they produce concentrated sludge which create a disposal problem (Pearce et al., 2003). Excessive used of chemical in dyes treatment might create secondary pollution problem to the environment. According to the Integrated Pollution Control (IPC) regulations, any decoloration systems involving destruction technologies will prevail as a transferral of pollution from one part of the environment to another is prevented (Willmott et.al., 1998). Treatment using ozonation, Fenton's reagent, electrochemical destruction and photocatalysis are some of the emerging techniques, which reported to have potential for decolorization.

However, such technologies usually involved complicated procedures or are economically unfeasible (Chang & Lin, 2000). Kamilaki (2000) considered a treatment system that can offer an effective dye removal from large volume of wastewater at a low cost as a more wanted and preferable alternative in solving textile wastewater problem and this can be achieved through biological and/or combination treatment system. Bioremediation using microbial biocatalysts to reduce the dyes present in the effluent offer potential advantages over physio-chemical processes. Such system has become the focus of recent research. However, many aspects need to be investigated in order to really gain advantage from the system.

1.3 Aim of Study

The aim of this study is to identify alternative method in treating textile wastewater.

1.4 Objective

The objectives of the study are

i. To develop and characterise the aerobic granules that are formed in a Sequential Batch Reactor (SBR) system.

ii. To study the color and COD removal from textile wastewater by using aerobic granule in the SBR system

1.5 Scope of Study

A laboratory scale of sequential batch reactor system will be used in the development of the aerobic granule. Synthetic textile wastewater is used during the development process and sodium acetate is added as the primary carbon. Sludge from the biological treatment system of Ramatex textile industry, located at Sri Gading Industrial Area in Batu Pahat, Johor is used as the seed sludge in the development of the granule.

1.6 Significance of Study

The outcome of the study is expected to produce a better biological treatment system in removing colour and organics from textile wastewater. This will solve the problem of coloured effluent generally related to textile industry.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biogranulation

Biogranulation is a developing technology in wastewater treatment. It applies the principles of using whole bacteria cell in mixed cultures. In biogranulation, granular sludge has become the core component of the bioreactor system. Granulation implies the immobilization of active anaerobic sludge into discrete macroscopic aggregates retained within a system. Biogranules consist of dense microbial consortia packed with different bacterial species mounted to millions of organisms per gram of biomass. It is formed through self-immobilization of microorganisms involving cell-to-cell interactions that include biological, physical and chemical phenomena. According to Calleja (1984), microbial granulation can be defined as the gathering together of cells to form a fairly stable, contiguous, multicellular association under physiological condition. These bacteria perform different roles in degrading the complex industrial wastes. Biogranules have a regular, dense and strong structure and good settling properties that are able to withstand high biomass retention, strong-strength wastewater as well as shock loadings (Liu et al. 2003; Liu & Tay, 2004).

Wirtz & Dague (1996) have listed briefly several advantages of having granular biomass over flocculent biomass, granulations:

- Allows high biomass concentration in continuous reactors
- Leads to internal physiochemical gradients within the aggregates
- Leads to heterogeneous structured populations of syntrophic microorganisms
- Allows reactors to be operated continuously beyond normal washout flow rates
- Allows the manipulation of biomass as a single phase
- Affects overall stoichiometry, rate of growth and metabolism
- Allows the manipulation of growth rate independent of the dilution rate

- Generates a reactor effluent with low suspended solids

Anaerobic wastewater treatment biotechnology has extensively advanced for the past two decades by the development of the innovative upflow sludge bed (USB) type reactor concepts such as upflow anaerobic sludge bed (UASB), anaerobic baffled reactor (ABR), upflow anaerobic solids removal (UASR), hydrolysis upflow sludge bed (HUSB), upflow acidogenic substrate precipitating (UASP), elutriated phased reactor (EPR) as well as expanded granular sludge bed (EGSB) (Bachman et al., 1985; Lettinga et al., 1997; Zeeman et al., 1997). The success of these anaerobic systems is related to their capacity for accumulation of good settling biomass without the need of a biomass carrier, allowing high solids retention time and process stability with simple and low-cost equipment (Ahn & Richard, 2003). The UASB is considered as the best reactor with high carbohydrate containing wastewater being most likely to achieve reliable granule formation (Uyanik et al. 2002).

However, anaerobic biogranulation has a drawback of a very long period for development of stabilized granular system making attentions diverted to aerobic granulation system for wastewater treatment system (Morgenroth et al., 2004; Tay et al., 2002; Pol et al., 2004).

2.2 Aerobic Granulation

Many previous research have shown that aerobic granules have compact and strong microbial structure within the granular. Aerobic granules have advantages by having fast start-up and fast granule development, excellent settleability, clear-out shape and compact structure, high biomass retention and strong ability to withstand high organic loading rate (Chen et al., 2007). Nevertheless, actual mechanisms involved in aerobic granulation are not clearly understood. Many studies have been conducted in order to understand the process engaged in the aerobic granule formation. Hydraulic selective pressure and the exchange ration in the SBR are the two main driving forces that have significant effect on the development of stable aerobic granule (Liu & Tay, 2002; Pan et al, 2004, Tay et al., 2004). It is reported that the time allowed for sludge settling was one of the main parameter to select for growth of bacteria in well settling granules in SBR (Buen et al., 1999). Other factors that may have influences on the characteristic of developed aerobic granules are the substrate composition, substrate loading rate, feast-famine regime, feeding strategy, the concentration introduced into the reactor system, configuration of reactor, the solid retention time and cycle time.

2.3 Mechanisms of Aerobic Granulations

Aerobic granules was formed through a gradual process from seed sludge to compact aggregates then further to granular sludge and finally to mature granules (Tay et al., 2001). Aerobic granules that was developed in SBR seeded with anaerobic granules are quite different from the one seed with sludge. The anaerobic granular sludge will disintegrated into small flocs and debris with irregular shape under aerobic conditions. This flocs and debris will become the nucleus for the development of aerobic granules. The flocs and debris will then recombined with sludge under aerobic conditions and finally grow bigger resulting in the formation of aerobic granular sludge (Linlin et al., 2005). The structure of aerobic granules contains of biomass, extracellular polymer substrate (EPS), inorganic precipitates, bound water and cavities (Sponza, 2002).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Research Material

3.1.1 Synthetic Textile Wastewater

The synthetic medium prepared for this experiment represent a mixed dye containing three types of synthetic dyes namely sf red, blue and black with a total concentration of 100 mg/L. Necessary micro and macronutrients such as CH_3COONa, NH_4Cl , KH_2PO_4 and $CaCl_2.2H_20$ are also added to the medium.

3.1.2 Acclimatization of Dye Degrader Microbes

Three types of microbes have been selected from previous study for the granules development. They have been identified to have the best dye decolourisation ability among microbes inoculated from the raw textile wastewater. These three microbes are cultured and acclimated in the synthetic wastewater mentioned above at 37°C.

3.2 Research Design and Procedure

3.2.1 SBR Reactor Set-up

The SBR reactor was made of acrylic cylindrical reactor with an inner diameter of 8 cm and a height of 1 m and has 3-equal distance sampling port along the reactor height. The effective working volume of the system was 4 L. The reactor was seeded with 2 L of activated sludge. The sludge was sieved with a mesh of 600 μm to remove large debris and inert impurities of larger size. The temperature of the reactor system was maintained at 37°C by circulating hot water in the outer-water jacket. The influent pH was adjusted to 7.0 ± 0.5 by adding of 1M NaOH or 1M HCl.

3.2.2 Start-up Operation

The reactor system started with the OLR at 1.8 kg/m^3.day with sodium acetate as the main carbon source. The HRT of the system was at 12 hrs. Fine bubbles aerator at the bottom of the reactor system introduced air. The reactor system was operated in successive of 12 hours each with one complete cycle consisting of 10 min of influent addition, 340 min of aerobic and 340 min of anaerobic phase introduced intermittently into the reactor system, 10 min of settling, and 5 min of effluent withdrawal and idle of 5 min. Steady state was assumed after the test result were within 10% deviation among the samples taken.

3.3 Analytical Method

3.3.1 Sample Analysis

The sludge samples is withdrawn from the sludge bed of the reactor and were analysed for the sludge concentration, VSS/SS ratio, specific gravity and sludge volume index (SVI). Due to the limitation of sludge volume available in the reactor, the sludge characteristics were determined at the beginning and once a month during the operation process, with duplicate samples, for all experiments. Determination of alkalinity, COD, pH, sludge volume index (SVI), suspended solids (SS), volatile suspended solids (VSS) according to standard methods (APHA, 1995) was carried out. Determination of influent and effluent pH was carried out daily. COD determination was carried out twice a week.

3.3.2 Characterisation of Developed Aerobic Granular Sludge

3.3.2.1 Determination of Average Settling Velocity

A glass column of 7.5 cm in diameter and height of 75 cm filled with tap water is used for determination of average settling velocity of the sludge. About 25 mL of diluted sludge (5-10 times) is added to a glass column filled with tap water. Tap water is used for determination of settling velocity as well as strength, because pH and ionic strength of tap water is adequate for this purpose and the size of the granules may be sufficient to render them not affected by osmotic stress (Laguna et al., 1999). The amount of sludge settled at bottom is collected after regular time intervals (0.5, 1, 1.5, 3, 7.5, 15 and 60 min).

Concentration of SS is determined for each sample, which showed the fraction of sludge settled in that time interval. The average settling velocity is calculated as below:

$$\text{Avg. settling velocity} = \frac{\Sigma\,(\text{wt. of sludge fraction settled x settling velocity of fraction})}{\text{Total wt. of sludge sample}}$$

3.3.2.2 Determination of sludge granules size

When the reactor system has reached steady state, approximately 5-10 mL of biomass granules are randomly removed from the lower, middle and upper part of the sludge bed zone of the SBR reactor. The granule diameter, shape and size are determined using the method of image analysis (Chou et al., 2004).

3.3.2.3 Determination of strength of granules

Determination procedure used to investigate the granular strengths is described by Ghangrekar et al. (1996). The test is based on the principle that when the granules are subjected to fluid shear stress beyond some limit, the quantity of sludge released in the surrounding fluid would be a function of shear strength of the granules. The sludge sample from the bed of the reactor is diluted 10 times with tap water. The diluted sludge sample is allowed to settle in the glass column in order to separate the granules from the flocculent sludge. The fraction that settled in 1 min is used for determination of strength. The shear force is introduced by placing the settled granules in conical flask containing tap water making total volume of 150 mL on a platform shaker. The sample is subjected to a degree of agitation of 200 rpm for 5 min.

After agitation, the sample is allowed to settle for 1 min in a 150 mL measuring cylinder, followed by decanting of the supernatant and weighing of SS (mg) in the supernatant. Weight of residual granular sludge (mg of SS) is determined. The result is expressed as an integrity coefficient defined herein as, the ratio of solids in the supernatant to the total weight of the granular sludge, expressed in percent. Integrity coefficient can be interpreted as an indirect index for strength of granules. It is a kind of index indicative of strength of the granules against abrasion and shear, which granules often undergo during reactor operation. The lower the integrity coefficient, the greater is the strength of the granules

3.3.2.4 Determination of Mineral Content of Sludge

To determine the sludge mineral composition, the wet sludge sample is evaporated to dryness in an oven at 105°C. About 8-10g of dry sludge is ignited at 550°C for 1 hour and the ash is dissolved in a minimum quantity of concentrated nitric acid and warm distilled water for 48 hours. This is filtered through a pre-weighed 0.45 um membrane filter and diluted using distilled water to a total volume of 100 mL for metal determination. The filter paper is dried along with the residue at 105°C and weighed to give the amount of undigested ash residue consisting of inert material similar to silica and silt. Metals such as Ca, Mg, Na, P, K, Fe, Ni and Co are determined using Atomic Absorption Spectroscopy.

CHAPTER FOUR

RESULTS AND PROGRESS OF STUDY

4.1 Dye Degrader Microbes

Three types of microbes have been identified to have the best ability to degrade the dyes contained in the synthetic wastewater. These three microbes are used in the development of aerobic granules. Further analysis on the identification on the species of dye degrader will be carried out in this study.

4.2 Progress of Study

The development of aerobic granules is still in progress. Tiny yellow aerobic granules were observed in the reactor system after one and a half month of operation. These small particles are believed to be the early stage of granule development which with time will grow to form bigger, denser and compact granules. The dissolved oxygen content in the reactor varied in the range of 4 mg/L to the saturation concentration during the aeration phase. The air percentage in the reactor system was kept at above 80% during aeration phase, which is important for the aerobic granulation. The temperature of the reactor was at 37°C. During the granulation process when the pH of the synthetic wastewater in the reactor system was above pH 8 or below 6, the settling behaviour of the sludge become poor and caused more sludge washout during the decanting phase. These show that the pH of the influent may influent the formation of aerobic granules. The development of aerobic granulation will be in progress until mature aerobic granules develop. This mature aerobic granule will then be characterised according to the methods described in Chapter 3.

4.3 Financial Standing

To date, the study is being conducted under Sciencefund Research Grant (No. 02-01-06-SF0310).

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ACKNOWLEDGEMENT

The researchers would like to thank Research Management Center of Universiti Teknologi Malaysia for the research grant (Vot 74221). Without the grant, the study which is currently conducted under Sciencefund (No. 02-01-06-SF0310) would not have been materialised.