Ammoniacal Nitrogen Removal in Semiconductor Wastewater by Sequence Batch Reactor Using Bacteria Inoculum from WormTea

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***Abstract*—Two condition of treatment (aerobic and anaerobic) environment in SBR were applied. Three isolated bacteria from worm tea have been used in the semiconductor wastewater treatment; there are *Bacillus pumilus*, *Micrococcus lutues* and *Staphylococcus warnaeri*. The SBR were monitored 30 days, using synthetic semiconductor wastewater in the treatment which contained high concentration amount of NH_3N, 1000mg/L. The results showed efficiencies of removal of ammoniacal nitrogen by *Staphylococcus warneri* is 97.2% which remained NH_3N 30 mg/L, *Bacillus pumilus* is 60.7% and *Micrococcus lutues* is 79.2% respectively, and the highest microbial density of *S. warneri* was about 3.02 (optical density).**

***Index Terms*—ammoniacal nitrogen, nitrify, denitrify, sequence batch reactor, semiconductor wastewater**

I. Introduction

Semiconductor manufacturing process generated a significant amount of wastewater because a huge quantity of ultrapure water is consumed in the course of chemical mechanical polishing (CMP) process. It is generally used in the semiconductor industry for the purpose of planirizing the surface of silicon wafer [1]. High levels of ammonia, phosphate and fluoride are presented in semiconductor wastewater.

Among the pollutants, ammonia is a major concern. Ammonia can facilitate O_2 depletion, eutrophication and red tidal phenomena in water courses [2]. In addition, ammonia has a harmful effect and vaporizes in the ecology and environment. Therefore, the removal of ammonia from wastewater is important before it discharge into aquatic system.

There are a few methods for the ammoniacal nitrogen removal which are chemical, physical and biological treatment like adsorption, chemical precipitation, membrane filtration, reverse osmosis, ion exchange, air stripping, breakpoint chlorination and biological - nitrification and denitrification. However, the chemical and physical methods of treatment produced secondary pollutants which are form through chemical and photochemical reactions and toxic to humans [3].

Through Sequencing Batch Reactor (SBR) systems, wastewater is added to a single “Batch” reactor, to remove undesirable components, prior discharged [4]. This reactor works by loads repeating sequences such as filling, aeration, anoxic, sedimentation and emptying in a set time period, and within the same reactor. Each treatment length and both sequences, depends on the type of water to be treated and the organic matter or nutrient wanted to be remove.

The process of nitrification-denitrification is a microbial process which comprises of two phase. The first, known as nitrification, is an aerobic process and the second, known as denitrification, is an anaerobic process. The nitrification- denitrification process can be carried out in a sequence batch reactor (SBR) which is activated sludge, all performed within the same tank and achieving high nitrogen system used for the treatment of wastewater containing carbon and nitrogen [4].

Worm tea is an aerated solution that is teeming with billions of beneficial microorganisms. Worm tea as an organic fertilizer restores a much needed diversity and population of beneficial bacteria, fungi, and protozoa back into the soil food web [5].

In previous study, green alga Scenedesmus was investigated for its ability to remove nitrogen from anaerobic digestion effluent possessing high ammonium content which was the concentrations were 200–500 ppm NH_3–N [6]. Another study was conducted to treat the industrial wastewater with 300-600 ppm ammonium content using the nitrifying and denitrifying bacteria [7].

This study was conducted to investigate the removal of ammoniacal nitrogen in semiconductor wastewater which containing high concentration of ammoniacal nitrogen by three selected bacteria in two conditions (aerobic and anaerobic) in SBR system.

II. Methodology

A. Bacteria Strain

The bacteria were isolated from the worm tea from BP Gemilang Sdn Bhd. Bacteria were grown at pH 7.0 in Nutrient agar (Peptone 5.0g, Beef extract 3.0g, Sodium Chloride 8.0g, Agar 15.0g, Water 1.0L). In order to investigate the effect of ammonium, 157 mg/L of NH_4CL (41 mg-N/L) was used instead.

Manscript received July 30, 2013; revised September 30, 2013.

doi: 10.12720/jomb.3.4.241-244

B. Cultivation

Bacteria were inoculated in nutrient broth and incubated in incubator shaker for 48 hours at 37 ℃ in 150 rpm.

C. Description of Reactor

Bacteria were cultivated in the cylindrical glass reactor using 2 L blue cap bottle with a 900 mL working volume. The reactors were equipped with aerator, which generated an intermittent aeration and excess wastewater, and supply to reactor and an agitation system. The SBR operation cycles were controlled by manual. The reactor was inoculated with (density of bacteria) which was acclimated to nutrient broth and semiconductor wastewater contain high ammonia from company.

D. Wastewater

Synthetic semiconductor wastewater was prepared by using chemical which is same with semiconductor wastewater from CMP process in factory in terms of high concentration of ammoniacal nitrogen due to the charaterization of the factory wastewater in preliminary work.

E. Operational Strategy

The reactor operation was carried in a month. There were three different reactors using the same semiconductor wastewater and three different bacteria by using ratio 1: 2 of bacteria culture and semiconductor wastewater. This ratio was due to the preliminary work of this research. The cycles performed by the SBR reactor were always 12 h for aerobic process, where the reactions phase with aeration (12 h) and 12 h for anoxic and sedimentation stage, performing the filling in an average time of 35 min in the mixing and aeration cycle. Withdrawal of sample was done in a time of 5 min. All those process was conducted manually.

F. Wastewater Analysis

Various physicochemical parameters were evaluated such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5), Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS) in accordance with established protocols in the Standard Methods. Nitrates (NO_3–N) were determined by ion chromatography. Ammonium (NH_4^+–N) with a HACH reagent and distillation, Nessler methods and titration in accordance the protocol in the Standard Methods.

G. Determination of Nitrifying and Denitrifying Bacteria

Samples were taken during the aeration and anoxic phases to determine the population density of nitrifying and denitrifying bacteria present in the reactor. For sowing the most probable number technique (MPN) was utilized, using a selective medium for each group of bacteria as in the Standard Method procedure.

III. Result and Discussion

A. Effect of Aeration and without Aeration Condition in NH_3N Removal

Aeration provided significant benefits to ammoniacal nitrogen removal except for *S. warnaeri* and *S. pasteuri*. *M. lutues* and *B. pumilus* reduced more ammoniacal nitrogen in aeration condition than in without aeration condition. *S. warnaeri* reduced more ammoniacal nitrogen in without aeration condition. Denitrification occurs. Percentage of ammoniacal nitrogen removal using *M. lutues* and *B. pumilus* are 59.4% and 80.48% respectively, whereas are *S. warnaeri* 97.2%. (Fig. 1, Fig. 2, and Fig. 3).

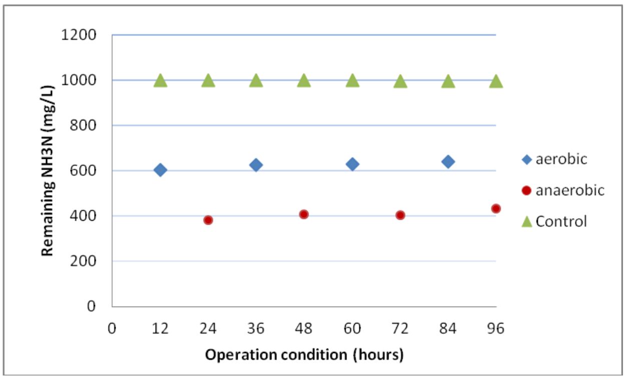

Figure 1. Effect of aeration and without aeration condition to NH_3-N removal in SBR using *M. lutues*.

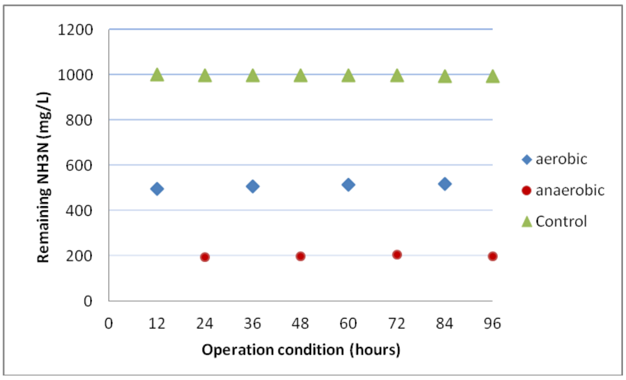

Figure 2. Influence of aeration and without aeration condition to NH_3-N removal in SBR using *B. pumilus.*

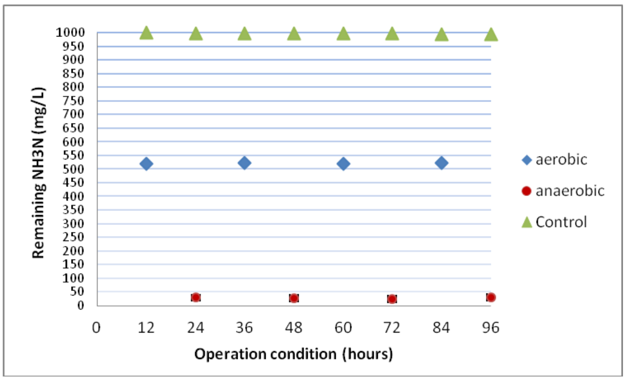

Figure 3. Influence of aeration and without aeration condition to NH_3-N removal in SBR using *S. warneri.*

B. Effect of Aerobic and Anaerobic Condition in Bacteria Optical Density

The optical density of *M. lutues* and *B. pumilus* in aeration were higher than in the aeration condition, whereas in *S. warneri* the density of bacteria in without aeration condition was higher than in aeration condition. However, density of *S. warneri* in aeration condition was higher compared to the density of *M. lutues* and *B. pumilus*. (Fig. 4, Fig. 5, Fig. 6)

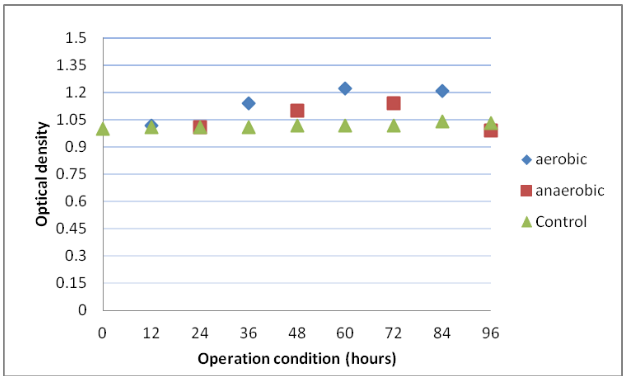

Figure 4. Effect of aeration and without aeration condition to *M. lutues* density in SBR.

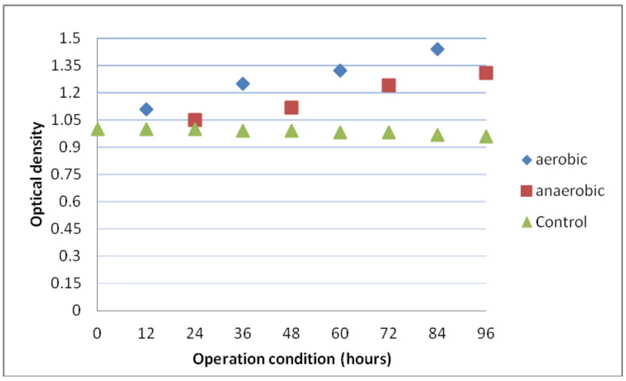

Figure 5. Effect of aerobic and anaerobic condition to *B. pumilus* density in SBR.

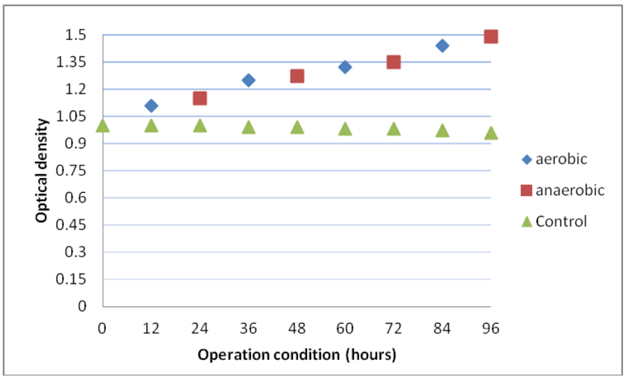

Figure 6. Effect of aerobic and anaerobic condition to *S. warneri* density in SBR.

The optical density of *M. lutues* was increase (Fig. 4) and the highest density ups to 1.2 A optical density which was at 60 hours in with aeration condition. However, the density decreases each time in without aeration condition. This is because they are generally strict aerobes and can generally reduce nitrate by conversion of nitrate to nitrite [8].

C. NH_3N Concentration/Profile for 30 Days.

This consistent with the physic chemical results, since the largest removal of NH_4^+-N was found at this period, this is due to the nitrifying bacteria, the nitrification step is carried out quickly and efficiently, without inhibition or accumulation in any stage (NH_4 to NO_2 and NO_2 to NO_3^-) on the other hand, the relationship between organic matter and nitrogen defines the type of bacteria.

The density of bacteria in Fig. 7 has a direct proportional relationship to the remaining of NH_3–N. The removal of NH_3-N in Fig. 7 by *M. lutues* was 60.7%. However, the removal of NH3-N by *B. pumilus* in Figure 8 was 79.2%. It showed that when the density of bacteria increased, the remaining of NH3-N decreased from 1000mg/L to 195mg/L and 97mg/L in Fig. 8 and Fig. 9 respectively, which means the removal of NH3-N increased. Conversely, when the amount of bacteria decreased (Fig. 7) removal was low; the remaining NH3-N was high.

This is because a larger population of nitrifying bacteria transforms NH_3–N to NO_2–N faster. Kargi and Uygur in 2002 [9] found that for a SRT of 30 days, the removal efficiency of NH_3–N was approximately 76%, whereas in this study it was approximately 97.2% for *S. warneri* as in Fig. 9.

The results of ammoniacal removal and density of bacteria down to the balance between these two parameters is adequate to promote growth nitrifying and denitrifying bacteria, thus achieving efficient removal of organic matter and ammonia nitrogen.

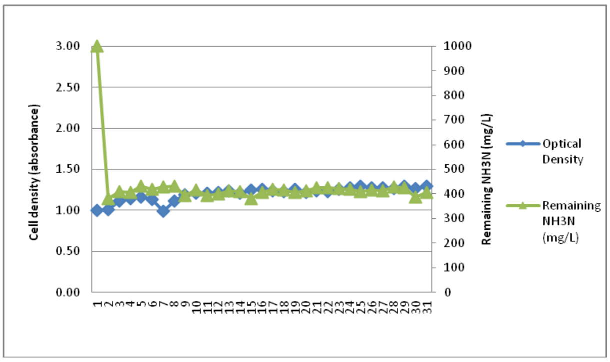

Figure 7. Remaining NH_3N in SBR using *M. lutues* in 30 days.

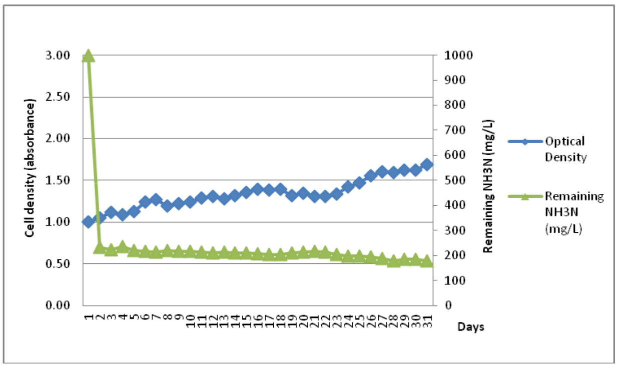

Figure 8. Remaining NH_3N in SBR using *B. pumilus* in 30 days.

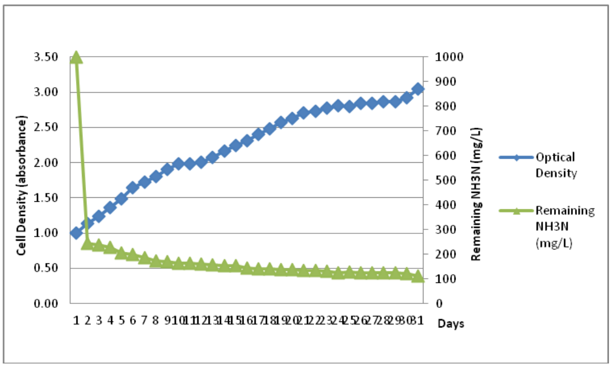

Figure 9. Remaining NH_3N in SBR using *S. warnaeri* in 30 days.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support from Silterra Malaysia Sdn Bhd for the Internship Postgraduate Programme. Authors wish to thank Universiti Sains Malaysia for providing the lab facilities in order to conduct the experiments. This work was supported in part by a grant from Postgraduate Research Grant (PTEKIND) and Silterra Malaysia Sdn Bhd.

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