Welcoming address

It is my great pleasure to welcome all of you to the 5th International Conference on Environment 2010 (ICENV2010). The conference’s theme is "Green Technologies for the Benefits of Bottom Billions". This conference will be a large technical event on environment focusing on green and sustainable development for the benefits of bottom billions. The bottom billions refer to the most populous nations of the world who are unfortunately in bottom segments of the socio-economic pyramid.

The main objective of this conference is to integrate green innovation and technologies from research-commercial settings into sustainable development so as to benefit the lowest segment of the society since they constitute the majority of the world population. I also hope that ICENV2010 be the appropriate platform to imbue and strengthen participants with the need to embrace ecological protection, conservation of resources and development based on the virtues of equity, accessibility, availability, affordability and appropriateness, in line with the vision of USM, which is "Transforming Higher Education for a Sustainable Tomorrow".

School has experiences in organizing many successful conferences, seminars and short courses. Elements that made earlier precedents successful have been retained in this conference and more surprising features be introduced to make this conference even more successful, stimulating and memorable.

On behalf of the organizing committee, I would like to thank the participants, speakers, committee members and sponsors for their tribulations. I am most indebted to the excellent team who plays a pivotal role behind the organization and contributes towards the success of the conference.

Thank you.

Professor Azlina Harun@Kamaruddin
Chairman, ICENV 2010
Universiti Sains Malaysia, Penang
Malaysia.
# Program Schedule

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Keynote Speaker
Professor Tan Sri Dato' Dzulkifli Abdul Razak 
Vice Chancellor
Universiti Sains Malaysia, Malaysia
"USM Response to the Environmental Challenges"

Plenary Speakers
Dr. Anil K. Rajvanshi
Director
Nimbkar Agricultural Research Institute, (NARI)
India
"Rural Innovations for Sustainable Development for Bottom Billions"

Professor David Marshall Porterfield
Department of Agricultural and Biological Engineering, Department Horticulture and 
Landscape Architecture
Purdue University, U.S.A.
"Biological Engineering for Integrated Approaches to Developing 
Sustainable Green Technologies"

Professor Graham 'Gus' Nathan
Director, Centre for Energy Technology
University of Adelaide, Australia
The Role of Integration in Lowering the Cost of Alternative Sources of 
Thermal Energy"

Professor Shigeo Fuji
Graduate School of Global Environmental Studies
Kyoto University, Japan
Procedure Development of Alternative Sanitation System Selection in 
Developing Countries Based on Their Constraints"

Professor Stephen Allen
School of Chemistry and Chemical Engineering
Queen's University Belfast, United Kingdom
"Adsorption-Whatever Colour the Cat as long as it 
Catches the Mouse"

Professor Malarne Mbarawa
Head of Department
Department of Mechanical Engineering
Tshwane University of Technology, South Africa
"Non-Edible Plant Oils as New Feedstock for Biodiesel Production"
Main Categories

Green Technologies
- Sustainable management of environment; wastewater, solids, hazardous waste
- Solutions and sustainable technologies for the benefits of bottom billons
- Air pollution mitigation, monitor, control technologies
- Carbon credit and carbon footprints
- Life cycle assessment, risk assessment, health and safety impact assessment
- Advances in natural resource exploitation and utilization
- Renewable technologies and new directions in solution of environmental issues
- Issues of energy in sustainable development
- Environmental awareness, policies and regulation
- Other related environmental issues
NITRIFICATION USING SUBMERGED MICRO BUBBLES DIFFUSER IN AN AERATION SYSTEM

WINARTO F. E. W. 2, KUTTY S.R.M. 1, GILANI S.U.U 2, ISA M.H. 1, AZNEN ANIZAM AB. A 1, WAN KARIMAH W. Z. 1

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ABSTRACT

The objectives of this research are to evaluate the effectiveness of the micro- diffuser in enhancing nitrification in wastewater treatment. The nitrification performances of micro- and milli- diffusers were evaluated by measuring NH4-N and NO3-N contents. The experimental values were also compared with the theoretical values derived from the kinetic calculations. Two reactors A and B, of size 140x140x500 mm were constructed using perspex to treat municipal wastewater. Aeration in the reactors A and B was provided using millimeter diffuser and micro diffuser, respectively. The diffusers consisted of perforated aluminium plate to generate millimeter bubbles and sintered porous glass to generate micro bubbles. Compressed air was forced through two parallel flow meters at a flow rate of 2.5 L/min. Biomass for both reactors was acclimatized prior to treating the municipal wastewater in the reactors. Two batch experiments were conducted at 26°C for the biological study and in the estimation of the kinetic parameters for the nitrification. Samplings were conducted at 1 hour, 3 hours, and every 6 hours respectively, until 48 hours for each batch of the experiment. The main parameters tested were NH4-N and NO3-N. The results of the study indicated that ammonia-nitrogen removal was achieved at 90% and 87%, for the micro- and milli- diffusers, respectively. The final average ammonia-nitrogen removal rate was found to be 0.48 mg/L.hr and 0.28 mg/L.hr, for micro and milli diffuser, respectively. The experimental degradation rate also closely follows the theoretical degradation rate with the theoretical degradation rate from 36-48 hrs. of aeration found to be 0.5 mg/L.hr and 0.46 mg/L.hr for micro and milli diffuser, respectively. It can be concluded that the use of micro diffuser can provide higher ammonia-nitrogen removal from wastewater.

Keywords: Millimeter diffuser; micro diffuser; NH4-N removal; NO3-N production; kinetics evaluation

INTRODUCTION

Air is often injected into wastewater to create aerobic condition for the bacterial degradation of organic matter. This provides mixing as well as oxygen, for mixing dissolved and suspended organic matter [1]. Aeration in wastewater treatment is mostly provided through subsurface and mechanical systems. Subsurface system is where air is introduced into the wastewater by diffusers or devices submerged in the wastewater, usually at the bottom of the aeration tank. Mechanical systems, on the other hand, agitate the wastewater using mechanical devices such as propellers and blades to introduce air from the atmosphere [2]. Coarse bubble diffuser is a type of subsurface aerator which involves huge input of energy and the oxygen transfer is sometimes inadequate to meet the process needs. This is due to the turbulence effect and the movement
speed that is caused by increased size of spherical air bubbles when they move upward. Size of air bubbles is one of the important factors to minimize the turbulence effect and decrease movement speed (spend more time to reach water surface). Besides, lifting the suspended particle requires a laminar air bubble rise [3]. Micro air bubbles provide larger interfacial area for oxygen transfer as the air bubble provides larger surface area to volume ratio. Decreasing bubble diameter from 2.5 mm to 0.5 mm would increase the interfacial contact area between air and water twenty-five times for spherical bubbles. This helps to fulfill the goal of aeration which is to dissolve oxygen into water [4]. Oxygen diffusion is influenced by the interaction between air and the wastewater. Degradation of organic matter and nitrification depends on the diffusion rate of oxygen into the water. By enhancing the oxygen diffusion rate, higher and faster organic matter removal can be achieved [5]. In the diffusion process, air in the atmosphere has a higher concentration of oxygen than water; hence oxygen diffuses or is pushed from the air into the water [1].

Submerged air diffusers are mostly used to increase dissolved oxygen (DO) levels and promote water circulation. Air or pure oxygen bubbles are released at depth, producing a free, turbulent bubble-plume that rises to the water surface due to buoyant force [6]. As the bubble plume ascends, it entrains water, causing vertical circulation and lateral surface spreading. Oxygen is transferred to the water across the bubble interfaces as the bubbles rise from the diffuser to the top water surface. There are two main interfaces over which oxygen transfer occurs; across the bubble interfaces as the bubbles rise through the water column and across the water surface at the air-water interface [6].

The bubble-transfer rate is a function of temperature and atmospheric, hydrostatic pressure and gas-phase oxygen composition [4,5]. Transfer of gases occurs as the bubbles rise, due to a concentration gradient between the equilibrium bubble concentration and the ambient water concentration. This affects the gas-phase oxygen composition and the equilibrium oxygen concentration. The gas flow rate and bubble-water transfer coefficient also affects the equilibrium oxygen concentration inside the bubble [4,5]. Nitrification is the oxidation of ammonia to nitrate and is affected by the activated-sludge floc size, floc density and total oxygen demand of the mixed liquor [6]. Growth of nitrifying bacteria (Nitrosomonas and Nitrobacter) is affected by the substrate (ammonia-N) concentration, temperature, pH as well as the oxygen concentration of the bulk liquid [7]. Oxygen is considered to be the essential factor for maximum nitrification, it was shown that partial nitrification or ammonium removal declined from 4.25 to 1.62 kg/(m³·day) when the oxygen concentration was decreased from 1.0 to 0.8 mg O₂/L [8]. These nitrifying bacteria are normally distributed within a floc containing heterotrophic bacteria and other solids, with floc diameter ranging from 100 to 400μm. Bacteria located within the floc are exposed to lower dissolved oxygen (DO) concentration as the oxygen from the bulk liquid diffuses into the floc particles. Hence, a higher bulk DO concentration would be needed to maintain the same internal floc DO concentration for nitrification to occur [6]. Better oxygen diffusion using micro- diffusers would help achieve this internal floc DO concentration.

OBJECTIVES

This study is to evaluate the effectiveness of micro bubble diffuser in the NH₄-N removal during degradation of organic matter.
EXPERIMENTAL SETUP
An experimental setup using two vertical reactors A and B, each of 140 mm length, 140 mm width and 500 mm height were used. A perforated aluminum disc (3 mm thick) with holes ranging in diameter from 0.1 to 0.4 mm was used to create millimeter size air bubbles in reactor A. Porous sintered glass with porosities in the range of 10-16 micron was used to produce the micro bubbles in reactor B. Compressed air at a pressure of 63 kPa and a flow rate of 2.5 L/min was forced through the diffusers placed at the bottom of the reactors. Figure 1 shows the schematic diagram of the experimental apparatus.

![Schematic diagram of experimental apparatus](image)

**Figure 1: Schematic diagram of experimental apparatus**

Experimental procedure. Biomass for ammonia and nitrate removal were taken from a municipal activated sludge plant and placed in both reactors. The biomass was acclimatized for 2 weeks prior to experimentation. 5 L of raw wastewater sample was treated in both reactors. Aeration was then provided through the perforated aluminium disc diffuser and the micro sintered glass bubble diffuser in reactors A and B, respectively. Aeration was continuously provided throughout the study. Samples were collected at regular time intervals of 1, 3, 6, 24 hours and every 6 hours thereafter. The samples were settled, filtered, diluted (1:20) and tested for ammonia-nitrogen (NH₄-N) and nitrate-nitrogen (NO₃-N).

RESULTS AND DISCUSSION

Removal of Ammonia. The removal of ammonia throughout the study period was plotted in Figure 2a below. It can be observed that the ammonia removal of the wastewater dropped gradually throughout the study period. Samples taken from Reactor B which utilized the micro diffuser showed lower effluent ammonia concentrations than samples from Reactor A which utilized the millimeter diffuser throughout the study period. The experimental data was expressed in the form of the kinetic modeling so that the first order coefficient rate, k or the rate of ammonia removal can be calculated to determine the effectiveness of the micro diffuser. After obtaining the first order coefficient rate k, the kinetic modeling graph was plotted for both reactors in Figure 2b. From the theoretical study, it was found that, the ammonia removal kinetic parameter, k, was found to be 0.062 and 0.053, respectively, for the micro and millimeter diffusers. Statistical T-tests conducted on both experimental and theoretical values indicated that there is a significant difference between effluent of ammonia removal from micro- and milli-
diffuser reactors at 5% level of significance. On average, micro and millimeters diffusers removed ammonia-nitrogen at approximately 90% and 87%, respectively.

![Graphs showing ammonia removal vs time for experimental and theoretical analyses.](image)

**Figure 2: Ammonia removal vs Time a. Experimentally, b. Theoretically**

The experimental and theoretical ammonia removal rate throughout the study period was plotted in Figure 3a and Figure 3b, respectively. It can also be observed that the removal of ammonia for Reactor B which utilized micro diffuser was as comparable to the ammonia removal rate of Reactor A which utilized milli diffuser. This indicates that faster ammonia removal rate was achieved using the micro diffuser. The final average ammonia removal rate was found to be 0.26 mg/L.hr and 0.3 mg/L.hr, for micro and milli diffuser, respectively.

The experimental ammonia removal rate plotted in Figure 3b also closely follows the theoretical ammonia removal rate with the theoretical ammonia removal rate from 22-50 hrs. of aeration found to be 0.29 mg/L.hr and 0.32 mg/L.hr for micro and milli diffuser, respectively. However, statistical analysis conducted throughout the study period indicated that both experimental and theoretical ammonia removal rates were significantly different at 5% level of significance for both diffusers.
Oxidation of Ammonia to Nitrate. The experimental and theoretical nitrate-nitrogen produced during nitrification were plotted in Figures 4a and 4b, below. It can be observed from Figure 4a that the degradation of ammonia to nitrate essentially stopped at 34 hours for Reactor B in the first trial of the experiment. The final effluent nitrate concentration stabilized at approximately 26 mg/L and 22 mg/L, for milli and micro diffusers, respectively at the end of the sampling period.

The experimental nitrate production also closely follows the theoretical nitrate production plotted in Figure 5b up to 34 hours with nitrate production rate $k_m$ to be 0.032 and 0.027, for micro and milli diffuser, respectively. Experimentally, the ammonia-nitrogen has been oxidized to nitrate-nitrogen at a faster rate for Reactor B which utilized the micro-diffusers. Effluent nitrate concentration from Reactor B can be seen to stabilize after 34 hours of aeration. Statistical $t$-tests conducted on both experimental and theoretical values indicated that there is a significant difference between effluent nitrate from micro- and milli-diffuser reactors at 10% level of significance.
Figure 4: Nitrogen removal vs time. a. Experimentally, b. Theoretically

The experimental and theoretical nitrate production rate throughout the study period was plotted in Figure 5a and Figure 5b, respectively.

It can also be observed that the nitrate production rate was generally higher for Reactor B after 18 hours of aeration. This indicates that faster nitrate production was achieved using the micro diffuser. The average nitrate production rate from 30-40 hrs of aeration was found to be 0.44 mg/L.hr and 0.33 mg/L.hr, for micro and milli diffuser, respectively. The experimental nitrate production rate also closely follows the theoretical degradation rate with the theoretical degradation rate from 30-40 hrs of aeration found to be 0.47 mg/L.hr. and 0.34 mg/L.hr. (average of the values) for micro and milli diffuser, respectively. Statistical analysis conducted indicated that both experimental and theoretical nitrate production rate were significantly different at 10% level of significance for both diffusers from 34-40 hours of aeration.
Figure 5: Nitrate Production vs time a. Experimentally, b. Theoretically

CONCLUSION
From the study it was found that the reactor with micro-diffuser achieved higher percentage removals of ammonia-nitrogen compared to the reactor with milli-diffuser. Similarly, slightly higher degradation rate of ammonia-nitrogen removal was achieved for the reactor using the micro diffuser. This shows that there is a potential use of the micro diffuser in wastewaster treatment.

REFERENCES
