J. Appl. Environ. Biol. Sci., 2(12)615-619, 2012

ISSN 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Effect of Light Exposure and Water Depth on the Performance of Algae Reactor during the Treatment of Surabaya municipal wastewater

Agus Slamet*, Joni Hermana

Environmental Engineering Department – Faculty of Civil Engineering and Planning
Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia, (62-60111).

ABSTRACT

The research was conducted to investigate the effect of light exposure and water depth on COD, nitrogen and phosphate removals to treat municipal wastewater using a series of lab scale algal bioreactors. The experiment was carried out using variables of sunlight during the day time and an artificial light during the night time, while it was run with the water depth ranging between 25 cm and 60 cm in a batch process. During the experiment, the COD concentration of municipal wastewater was set between 100 to 300 mg COD/l by adding glucose as a sole carbon source. The nitrogen and phosphate concentrations of influent were adjusted to the COD: N: P ratio of 30:4:1. The results showed that the maximum of COD reduction occurred in bioreactor operated in 25 cm water depth and with natural lighting during six days was able to remove up to 49%. The better nutrient removal occurred on 40 cm water depth, where the reduction of phosphate concentration up to 75 %; nitrogen as ammonia 98.8 % and nitrogen as nitrate up to 80.2 %. Additional lighting at the night was not able to improve the performance of algae bioreactor.

Keyword: *Light exposure, water depth, algal bioreactor, municipal wastewater.*

INTRODUCTION

The symbiotic utilization of algae and bacteria for wastewater treatment has been long developed as a high rate algae pond (HRAP) [1]. The HRAP combines the simplicity of method, an economical cost and its ability for processing municipal and industrial wastewater [1, 2]. Aeration system and algae productivity determine the HRAP performance [3, 4, and 5]. While it was reported that algae productivity was influenced by several factors, such as: light intensity, carbon and nutrient sources, substrate toxicity, retention time, temperature, dissolved oxygen (DO), pH and salinity [1, 2, and 6]. An experiment was conducted by Azov and Shelef [7] showed that aeration on the algal ponds could increase the BOD and COD removal efficiency of domestic wastewater until 94% and 91%, respectively.

Surabaya city has several retention ponds, known as boezem, for receiving rain water. It is however, because of continuing pollution from untreated municipal wastewater, the boezem currently turns to become a natural algal pond. Algae pond the production of algae could be influenced by the DO concentration that varies during the day and the night times. Particularly, the DO shortage during the night is able to decrease the symbiotic performance between algae-bacteria. It is therefore, long exposure of light is presumed to force the algae to perform photosynthesis during the night time in order to produce oxygen and hence increase the DO concentration. This effect could be enhanced further by the adjustment of water depth to assure the diffusivity of oxygen concentration those results in the algae productivity.

The objective of this research is therefore to assess the effect of light exposure during the night time and to define the water depth of the algal reactor in order to increase the removal of COD, nitrogen and phosphate from the Surabaya municipal wastewater.

MATERIALS AND METHODS

A rectangular bioreactor was used during this research, with the effective dimension of 1.0 m x 0.3 m x 0.6 m. Aeration was introduced to the system to prevent the deposition of algae and to maintain the DO concentration during the night time. The research was carried out in a batch process with varied water reactor depths and the use of artificial lightings. The water depth variations were 25 cm, 40 cm and 60 cm, while the artificial fluorescents lighting was operated for 12 hours at night. Fluorescents lamps have a specification as an Osram type of Fluora ® 77 L 36 W/77 with the light intensity equals to 1400 Lux each using the total of 4 units that bring to the intensity of 5600 Lux. It was the minimum requirement for the photosynthesis process by *Chlorella vulgaris* and *Chlorella pyrenoido* species [7]. The addition of these lights was aimed to force algae to conduct photosynthesis during the night. The research started by measuring the quality of municipal wastewater from Boezem Morokrembangan at west of Surabaya. Waste water is taken from the south side of Boezem

***Corresponding Author:** Agus Slamet, Doctorate Student, Environmental Engineering Department, ITS Surabaya. Email: agus_mgt@yahoo.co.id

during the week and twice a day in the morning and at night. The amount of waste water which is taken as much as 2 litters to be measured the concentration of COD, BOD, ammonia nitrogen, total nitrogen and total phosphate. Experiment was conducted in two steps. The first step was acclimatization period by using algae seeds from the Kalidami Boezem at the eastern part of Surabaya for starting up the process until the steady condition was reached. Mostert [8] stated that acclimatization period normally needs between 6 – 10 days. In this study, the acclimatization was reached approximately for a week, by adding cane sugar and Urea as a feed for microorganism in the reactor with the total ratio of COD : N : P = 30 : 4 : 1. The result of acclimatization showed that the optimum condition for algae growth was achieved at the ratio of COD: N: P = 106: 16: 1. The second step was the experiment that used the two main variables, namely water depth and lighting in the reactor, with the initial COD concentration of wastewater was set at 200 mg/l. The lighting duration was conducted by using both natural and artificial lightings at night time. The sample was taken in the morning and in the evening everyday to monitor the removal efficiency of COD, nitrogen (as ammonia and nitrate) and phosphate (as orthophosphate) and algae concentration which measure as *Chlorophyll-a*. All parameters was analyzed by closed reflux titration method, while ammonia, nitrate and phosphate were analyzed by spectrophotometer methods as described by APHA [10]. Before analyzed, the samples were filtered with what man 42 filter paper by using a vacuum pump.

RESULTS AND DISCUSSION

The effect of lighting time on COD removal.

Figure 1 shows the experimental results for COD removal. The experiment of water depth variations showed that the DO concentration has an opposite correlation with the water depth, the deeper water depth, the lower the DO concentration. it looks that the COD removal has also similar trend with the profile of DO concentration, where the higher COD reduction occurs at upper depth. It is similar with stated by Oswald et al. [1] that the most optimal performance of algal pond on water depth between 20 cm - 40 cm, both in the production of algae as well as for the self purification.

The experimental result with the addition of lighting at night was also described in Figure 1. It was expected to force algae to conduct more photosynthesis processes and hence to avoid the competition between bacteria and algae in oxygen consumption. Thus, the bacteria were able to degrade organic compounds as much as possible. The research then confirmed that the additional lighting at night did not affect on algal photosynthesis processes. During the day time, the bioreactor performance with natural lighting yielded a greater COD removal than the COD removal of the bioreactor with additional artificial lighting. The maximum COD removal was 49 % for initial COD concentration ± 200 mg/l for the bioreactor with natural lighting, while it was only 39% COD removal during the night time. This result was 46 % lower than previous results reported by Banat et al [11] that conducted integrated experiment using facultative pond followed by HRAP with the initial COD concentration of the domestic wastewater was 400 mg/l.

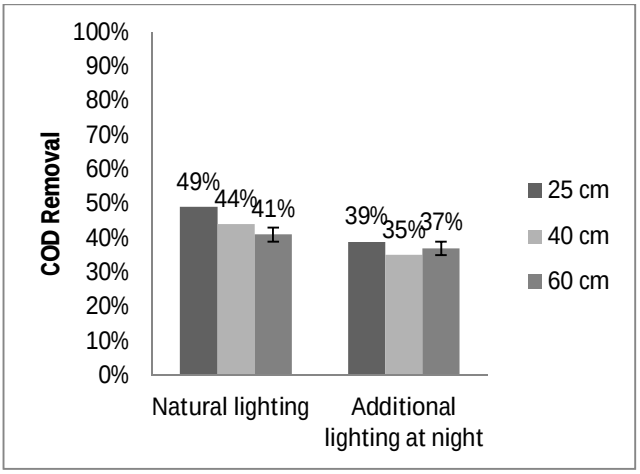

Figure 1: COD removal for natural lighting at day time and artificial lighting at night time

The effect of lighting time on nutrient removal.

Algae usually tend to absorb nitrogen as ammonia rather than as a nitrate, where ammonia is easier to be synthesized into amino acids as compared with nitrate [9, 12]. The experiment result for natural lighting at day time and artificial lightings at night was described in Figure 2. The results showed that the performance of bioreactor with natural lighting at day time had a nutrient removal greater than the nutrient removal with

prolong lighting at night. Where, the greater ammonia removal (98.8% as NH_3^+ - N) was occurred in the bioreactor with natural lighting during the water depth of 40 cm.

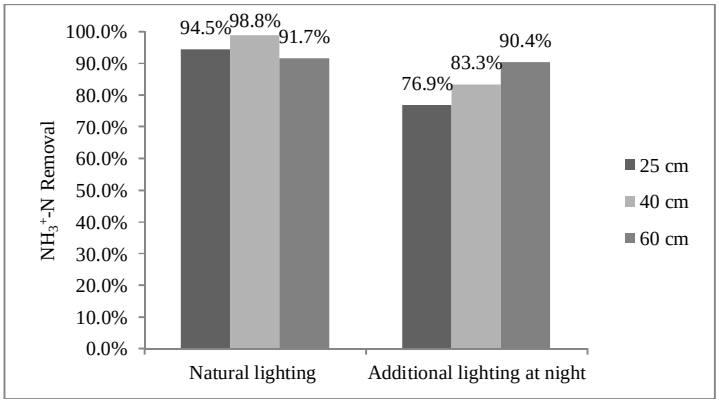

Figure 2: NH_3^+ - N removal for natural lighting and additional artificial lighting

The experimental results with the artificial lighting at night showed that the increasing of water depth has improved the removal of NH_3^+ - N. This suggests that the artificial lighting at night has driven the growth of algae, thereby increasing the removal of NH_3^+-N. The highest reduction of NH_3^+-N was occurred in the 60 cm water depth with removal efficiency up to 90.4 %. Changes in nitrate concentration of the wastewater generally occurred due to the process of nitrification and de-nitrification. The nitrification rates are influenced by the concentration of DO, temperature, substrate concentration, pH, and the number of nitrifying bacteria. The DO concentration above the critical limit (> 2 mg / L) is essential for good nitrification [13]. In this research, the averaged DO concentration between (2,5 – 6,5) mg/l.

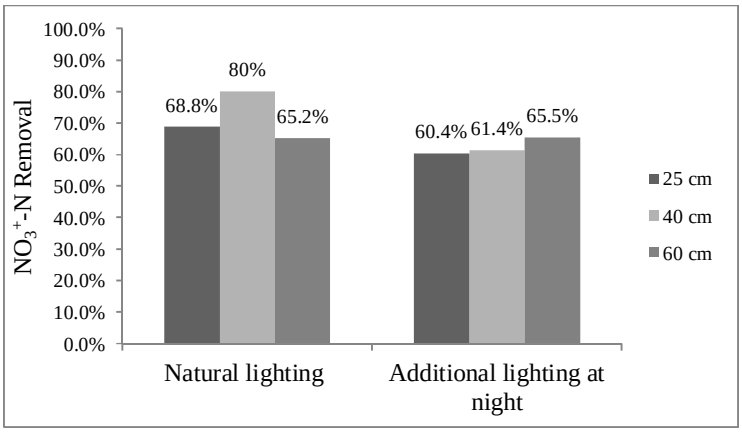

Figure 3: NO_3^- - N removal for natural lighting and artificial lighting.

The addition of lighting at night is expected not only to improve removal of COD concentration but also to increase the processes of nitrification and de-nitrification and lowering the nitrogen content in water. Figure 3 illustrates the removal efficiency of nitrate with different light exposure experiments. The experiment with natural lighting could reduce greater nitrate concentration than the nitrate removal with artificial lighting at night. It is estimated that the exposure of lighting only during the day time was able to increase the de-nitrification process. The highest nitrate reduction was occurred in the 40 cm water depth with the nitrate removal efficiency up to 80 %. Research showed that additional lighting using fluorescent lamps as a source of artificial light did not give significant effect on nitrate removal on algal reactor.

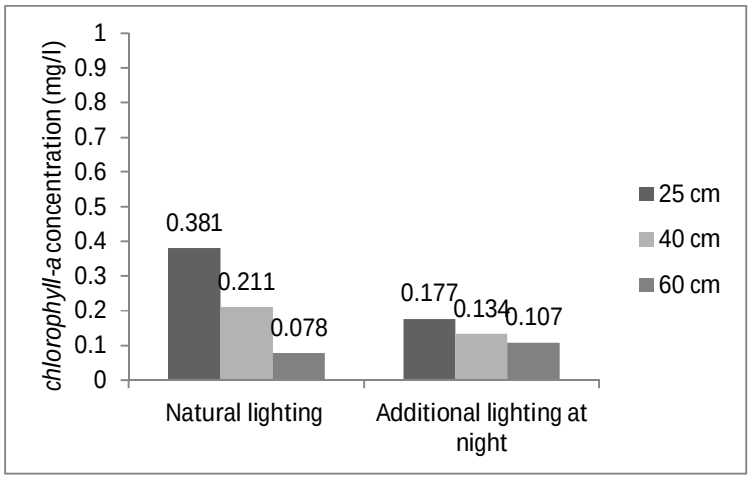

Figure 4: Alga concentration as *chlorophyll-a* during experiment for natural lighting and artificial lighting

Figure 4 shows that the algae concentration which measured as *chlorophyll -a* was decreased at the deeper water. This result was similar with theory by Oswald et al. [1], which stated that the optimum depth for the algae growth should be in the range of 4.5 to 5 inches (about 12.5 cm), while the optimum depth for the research laboratory scale was in the range from 8 to 10 inches (20-25 cm). Research showed that prolong lighting with artificial light was not effect on algae growth. It probably algae getting stress due to excessive heat energy which inhibits the growth of algae.

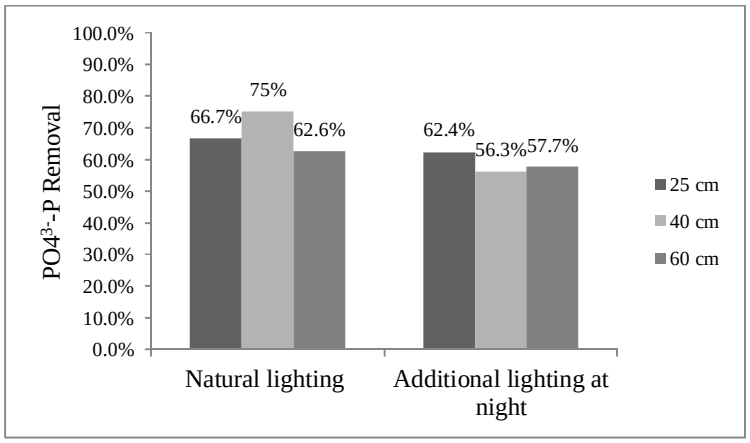

Figure 5: PO_4^{3-}- P removal for natural lighting and artificial lighting.

Phosphorus (P) is an essential nutrient for the growth of algae, but the amount of P for algae growth is less when compared with the need of nitrogen, as mentioned by Oswald et al. [1] that ratio of COD : N: P = 106:16:1. Chen et al. [13] stated that the mechanism that plays an important role in the P removal is an uptake by algal and immobilisation in sediments to form precipitate of calcium-phosphate. Figure 5 shows the result of experiment for phosphate removal. The research showed that the higher phosphate removal occurred in the shallow reactor due to the high content of *chlorophyll-a* and also the contribution of bacteria activity to phosphate uptake. The bacteria activity is very dependent on DO concentration therefore they are mostly clustered in the oxygen-rich zone [15].

The research using natural lighting and water depth variation showed that the higher phosphate reduction had occurred at the 40 cm water depth, where the removal efficiency reached up to 75 %. The experiment with lighting at night has a higher phosphate removal for the reactor with 25 cm depth, while phosphate removal for depth water at 60 cm slightly higher than for 40 cm depth. The additional lighting at night using artificial light could not increased algal reactor performance for phosphate removal. As described in the figure 4 that prolong lighting had inhibit alga growth and would affect phosphate absorptions.

During the observation on the concentration of *chlorophyll-a* for each reactor, it can be concluded that the additional lighting with fluorescent lamp does not give a significant effect on the increasing concentration of

algae. A result of this research shows that additional lighting at night could not improve algae growth, and affect on removal of COD and nutrient.

CONCLUSION

The alga productivity was not affected with prolongs lighting duration at night, where reactor with sunlight or natural light exposure showed the best performance. The research showed that alga reactor is able to reduce organic matter of municipal wastewater as COD up to 49%, it was lower than the previous studies by other researcher. The alga reactor with water depth of 25 cm could remove phosphate up to 66, 7%, and up to 75 % e for reactor with water depth of 40 cm, whereas the highest removal of nitrogen as ammonia and nitrate occur at water depth of 40 cm with value up to 98.8 % and 90.4 % respectively.

REFERENCES

[1] Oswald W.J., Gotaas H.B., Golueke, C.G. and Kellen, W.R. 1957. *Algae in Waste Treatment*. *Sewage Ind. Waste*, 29(4), 437-457

[2] García, J., Green, B.F., Lundquist, T., Mujeriego, R., Hernández-Mariné, M., and Oswald, W.J. 2006. *Long term diurnal variations in contaminant removal in high rate ponds treating municipal wastewater*. *Bioresource Technology*, 97(14), 1709–1715

[3] Mihalyfalvy, E., Johnston H. T., Garreth M. K., Fallowfield H. J., and Cromar N. J., 1998. Improved Mixing Of High Rate Algal Ponds. *Water Research*, 32(4), 1334-1337

[4] Buhr, H. O & S. B. Miller. 1983. *A Dynamic Model. Of The High-Rate Algal-Bacterial Wastewater Treatment Pond*. Water Res. Vol. 17, pp 29-37,

[5] Cloete, T.E., Roux J. D., Toerien D. F, & Pieterset A. J. H., 1983. *Oxygen Dynamics and Heterotrophic Aspects of a Pond Treatment System for Cattle Feedlot Effluent*. *Agricultural Wastes.* Volume 7 (3) 147-174.

[6] Grobbelar, J.U., Soeder, C.J., Groenegweg, J., Stengel, E. and Hartig, P. 1988. *Rates of Biogenic Oxygen Production in Mass Cultures of Microalgae, Absorption of Atmospheric Oxygen and Oxygen Availability For Wastewater Treatment. Water Research,* 22 (11), 14591464,

[7] Polprasert, Chongkrak.1996.Organic Waste Recycling. Thailand : Asian Intitue of Technology

[8] Azov, Y., and G. Shelef. 1982. Operation of High-Rate Oxidation Ponds Theory and Experiments. Water Res. Vol. 16, pp 1153-1160

[9] Mostert, E.S., and Grobbelar, J.U. 1987. *The influence of Nitrogen and Phosphorus on Algal Growth and Quality in Outdoor Mass Algal Cultures. Biomass*, 13(4), 219-233

[10]American Public Health Association (APHA), American Water Work Association, Water Environmental Federation. 2005. 31th edition. *Standard Method for Examination of Water and Wastewater*.

[11] Banat, I., Kazmer Puskas, Ismail Esen, Reyad Al-Daher. 1990. Wastewater Treatment and Algal Productivity in an Integrated Ponding System. Biological Wastes 32 265- 275

[12] Graham, Linda E. & Lee W. Wilcox. 2000. "Algae", USA: Prentice-Hall ???

[13] Hargreaves, John A. "Photosynthetic suspended-growth systems in aqua culture". Aqua cultural engineering 34 (2006) 344-363

[14] Chen. P., Zhou, Q., Le, Q. 2003. "Nutrient Removal by Integrated use of High Rate Algal Ponds and Macrophyte Systems in China". Water Science and Technology 48 No. 2 pp 251-257).

[15] Van Lossdrecht MCM, Hooijmans CM, Brdjanovic D,Heijnen JJ (1997). Biological Phosphate Removal Processes. Mini Review, App Microbiology Biotechnology,48: 289 – 286.