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The Feasibility of Algae Treatment Treating Fecal Sludge Wastewater at Surabaya, Indonesia

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Abstract: This research work was preliminary, carried out to determine the performance of algae in the fecal sludge wastewater treatment. This study was conducted with a batch scale, using an algae reactor to treat fecal wastewater with high organic and nutrient contents. Cultured algae using *Chlorella* sp. was spiked in domestic wastewater with five days detention period. Environment conditions such as pH, dissolved oxygen, light and temperature were monitored. It was seen that light intensities directly could affect the temperature of the bioreactor. The algae reactor was able to remove 20-50% of COD, 30-40% of nitrate and 50% of phosphate. A high correlation was discovered between organic substance and nutrient removal efficiency. Reducing organic substance was pursued with increasing dissolved oxygen concentration. The microalgae process was found feasible for treating fecal sludge wastewater considering with bacteria-algae symbiosis.

Key words: Algae, domestic wastewater, nutrient, organic substance.

Introduction

Domestic waste management is divided into two types: on-site maintenance and off-site maintenance. Indonesia has almost 60% of wastewater management with onsite systems (Linke, 2013). Fecal sludge is a domestic sewage with onsite management produced from a septic tank. Fecal wastewater has a higher pollutant concentration compared to sewerage (pipeline system) wastewater. Therefore, it is necessary to treat wastewater from fecal sludge with an appropriate natural process (Taziki et al., 2016; Zhu et al., 2013). Algae technology believed to be as potential green energy without producing additional waste (Sinha et al., 2015). Currently, there are a number of on-going research on the treatment of industrial, municipal and agricultural wastewaters by microalgae culture systems (Farahdiba et al., 2018; Iasimone et al., 2018). Wastewater treatment using algae has a high potential to reduce high organic and nutrient wastes (Taziki et al., 2016). In the natural system, bacteria and algae are interconnected. Symbiotic relation with bacteria will reduce high organic wastewater content, while algae can reduce high nutrient concentrations, which is usually found in domestic waste (Liao et al., 2018).

Nonetheless, there is a lack of references regarding the potential of the algae for treating wastewater from fecal sludge. In addition, it is necessary to

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dilute the original fecal wastewater when the nutrient concentrations are high, but the optimal removal nutrient and organic carbon are still unknown. This research could be used as an alternative process to treat fecal sludge wastewater, since it is one of the major issues in a developing country. The aim of this study was to measure the capability of *Chlorella* sp. contact with fecal wastewater and to determine its efficiency removal of organic pollutant.

Material and Methods

Domestic wastewater was taken from the fecal sludge wastewater treatment (FSWT) plant in Keputih, Surabaya. Keputih FSWT has a complete stage of the domestic wastewater process. Raw domestic wastewater in this research was carried out from the solid separation chamber (SSC) and oxidation ditch (OD).

The laboratory-scale research utilised pure microalgae cultivation seeds, *Chlorella* sp. obtained from the Brackish Aquaculture Fisheries Center, which were made from polypropylene plastic, dimension p = 40 cm, l = 20 cm and h = 25 cm. Microalgae cultivation is carried out by disposition of pure *Chlorella* sp. seeds into transparent tubs with adding the requirement mineral water according to the amount of pure *Chlorella* sp. cultivation. The fertilizer (containing N, P and K) was added as a supplement for algae growth. An aerator was installed in each reactor for increasing the dissolved oxygen concentration. The top of the tub was covered with transparent plastic to avoid contamination from insects with air circulation design in small perforated ventilation. Each sample for the analysis required an insoluble form. Wastewater components were immediately filtered using a 0.45 µm filter paper. Daily analysis of COD, nitrate (NO_3-N) and phosphate (PO_4^{3-}) with spectrophotometer methods was measured, based on the standard methods (APHA, 2003). The environmental condition was monitored for dissolved oxygen (DO) by DO meter (Lutron), and pH by pH meter (Trans instrument).

The duration of cultivation is around 5 to 7 days with irradiation from an LED lamp with 3,000 lux of 16 hours and 8 hours off (in the night). The initial concentration of the *Chlorella* sp. reactor starts with an additional 10% concentration of raw waste (Table 1). Additional raw wastewater was gradually mixed periodically from 10% to 40% raw wastewater. Dilution factor is 10% of raw wastewater measure with a composition of 4.5 L groundwater and 0.5 L wastewater. Freshwater was used for diluting other minerals, which benefit the microalgae. The experiment was controlled by decreasing value of nitrate and phosphate, which can be removed by microalgae. The performance of microalgae contact with wastewater in specific concentration could be determined. Data analysis were performed with EXCEL (Microsoft Office Enterprise, 365), Minitab 2016 for Windows and correlation was determined by Pearson correlation. Pearson correlation interpretation could be used with analysis. This study was performed using medical analysis (science) (Akoglu, 2018).

Table 1: Additional raw wastewater in microalgae reactor

Wastewater Concentration (%)	*Time Analysis (days^{-1})*
10	0
20	1
30	2
30	3
40	4
40	5

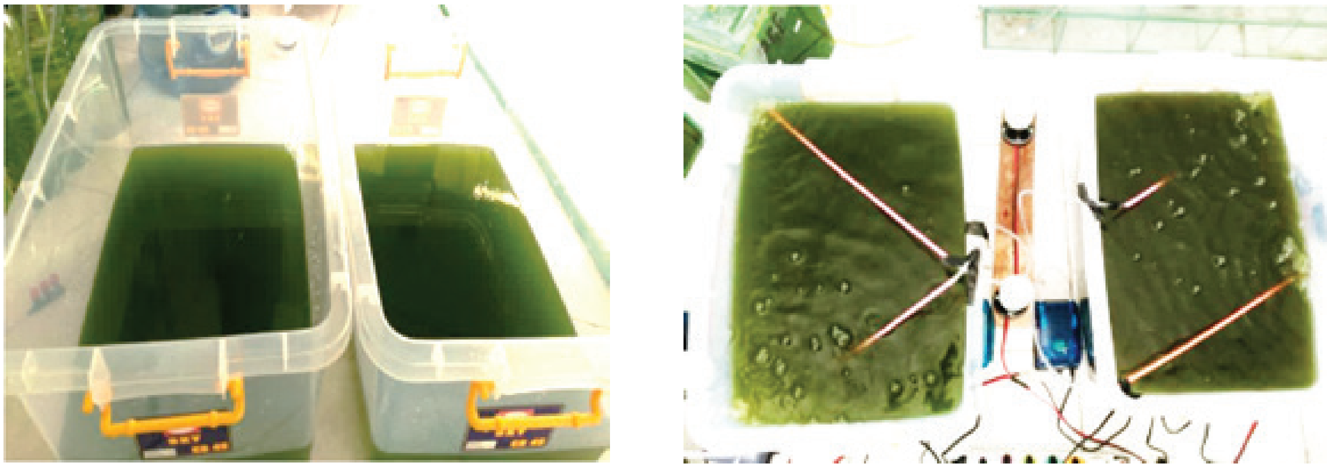
Results and Discussion

Visual Acclimatization of Microalgae

Physical observation is presented in Figure 1. The colour of microalgae, which was fresh green, turns to brownish green. On the first day of the physical observation, microalgae showed as fresh green. In the period of the 40% additional raw wastewater, microalgae became brownish green on the fourth day until the fifth day. This result indicated that *Chlorella* sp. could not receive a higher concentration of wastewater; therefore, 40% of additional wastewater was used as a baseline for further experiments. The colour of microalgae also experienced an adequate significant change, from dark green to yellow. After observing for several days, there was no change in the colour of the microalgae.

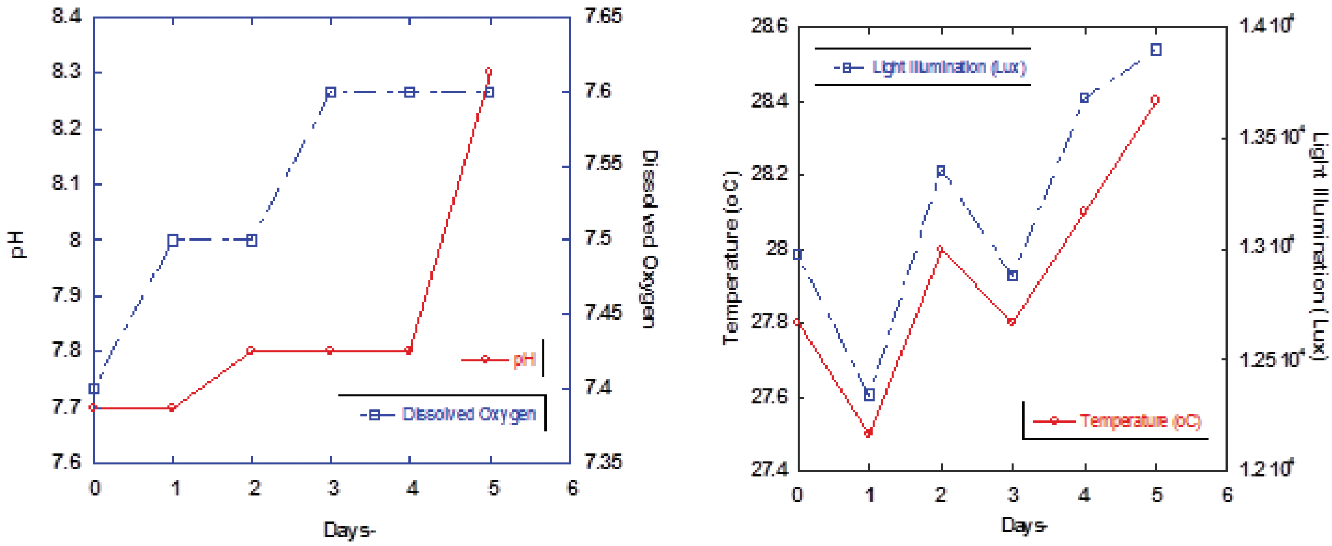
Effect of Domestic Wastewater on the Environment Condition (pH and Dissolved Oxygen)

Environmental conditions in microalgae reactors are very influential in the ability to reduce domestic waste. pH conditions that correspond to the microalgae environment to develop are between normal pH range i.e. pH 7.5 to 8.5 (Liu et al., 2007). This research has performed in the normal pH range of 7-8 (Figure 2). This result shows that microalgae can develop optimally in reducing domestic waste.



(a) (b)

Figure 1: Visualization of *Chlorella* sp. within experiment: (a) The first day, 10% addition of raw wastewater. (b) The fifth day, 40% additional raw wastewater (last day treatment).



(a) (b)

Figure 2: (a) pH and Dissolved oxygen condition in *Chlorella* sp. (b) Correlation between temperature and light illumination (Lux).

Dissolved oxygen on *Chlorella* sp. is shown in Figure 2. The range of DO values is ±7.4-7.6 mg/L. The process of photosynthesis in microalgae will increase the mutualism symbiosis between algae and bacteria in the reactor. The dissolved oxygen around 7 mg/L is still on the reasonable range for biological processes while in the range 7.8±0.1 mg/L (Ansa et al., 2011; Farahdiba et al., 2019).

Effect of Light Intensities on Temperature

Temperature and light were considered as an environmental factor for better microalgae growth. Previous studies have found that the optimum water temperature ranges from 15 to 30^0 C was suitable for algae biomass growth, otherwise microalgae cell could damage or lyse. Another investigator observed that 20–25^{o}C temperature was suitable for the growth of *C. pyrenoidosa* (Karsten and Holzinger, 2012; Singh and Singh, 2015).

Light intensities of *Chlorella* sp. reactor reach ± 12,000 Lux. This lighting reaches 192.44 µmol/s/m^2 (waveform). *C. minutissima*, another algae species, could grow under irradiances from 30 µmol/s/m^2 to 550 µmol/s/m^2 under light:dark cycle (day:night). This required minimum irradiance to sustain net growth (Singh and Singh, 2015).

This study conjectured that light intensities could enhance the performance of *Chlorella* sp. to treat domestic wastewater (Figure 2). Statistical analysis has proved that light intensities could affect the temperature directly, as shown by Pearson correlation 0.980. It interpreted that light intensities has a very strong correlation with temperature (Akoglu, 2018).

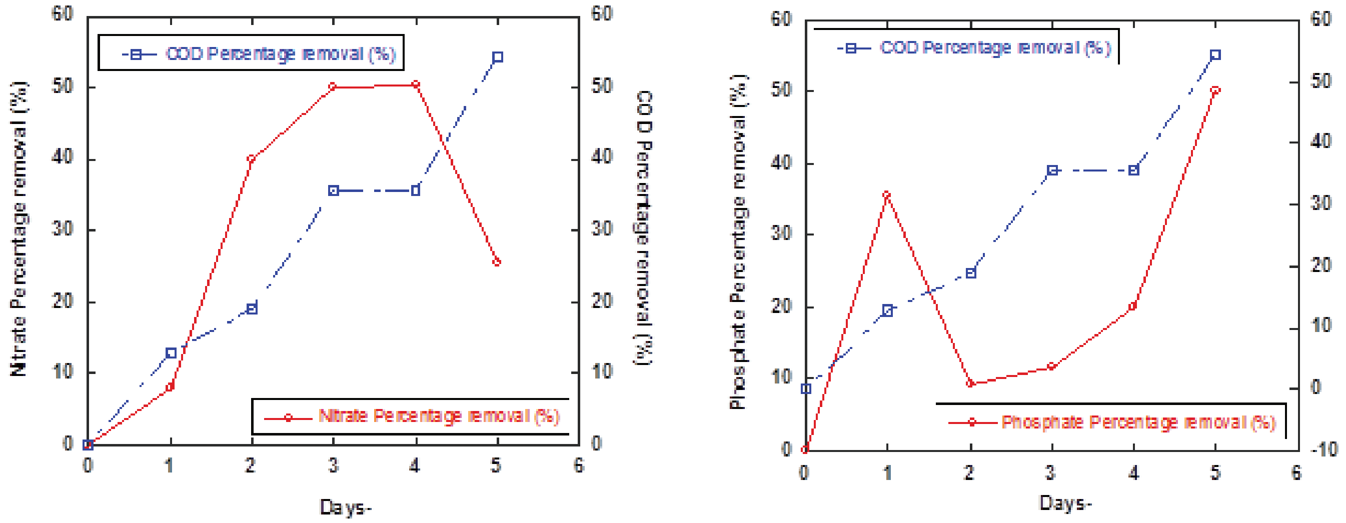
Removal of Nitrate and Phosphate by *Chlorella* sp. Decreasing of nitrate and phosphate levels during the experiment indicated that microalgae continued to develop and could adapt to the changing environment for less than 40% wastewater for five days exposure (Table 1). This research was conducted in 5 days experiments that are similar to previous research expected within 5 days experiment, which could represent lag-phase microalgae growth. Reducing nitrate concentration indicated N as a source for growth develops on the first day until the fourth day (Taziki et al., 2016).

Initial nitrate concentration is around 11 mg/L, while percentage removal could reach 50% on the fourth day (Figure 3). This condition has similar results with previous studies that microalgae could reduce the concentration of pollutants wastewater until ±55% with *Chlorella vulgaris* in the 0.62 mg/L NO_3^-. It shows a much lower performance than this study and a higher nitrate concentration in the bioreactor. Furthermore, another researcher developed other microalgae species have higher removal efficiency until 80% by *A. falcatus* from aquaculture wastewater (Ansari et al., 2017).

Nitrate concentration started stabilising until the fourth day in the 6 mg/L until it almost depleted. Nitrate concentration increased until 9 mg/L subsequently. Nitrate began to accumulate, and started to exceed the process on the fifth day. This has similar trends with the previous study that nitrate concentration could accumulate around 13 mg/L. Symbiotic algae-bacteria could affect the nitrate removal performance. Bacteria could compete with microalgae for ammonium utilisation and nitrate accumulation until the complement state (González-Camejo et al., 2018). Phosphate removal rates in 5 days reached proportionally to ±50% with initial phosphate concentration of 0.26 mg/L in the low concentration (Table 2). This presents higher removal efficiency than previous research (Putra and Farahdiba, 2018). Furthermore, this finding has lower capabilities than (Ansari et al., 2017; Peng et al., 2008; Selvaratnam et al., 2015) while the initial concentration of the pollutant beliefs could weigh the microalgae capability to remove phosphate as total phosphate (TP) or phosphate (PO_4^-) from water.

Table 2: Organic substance (COD), nitrate and phosphate concentration in microalgae bioreactor

Days/	*1*	*2*	*3*	*4*	*5*
COD (mg/L)	157	146	116	116	82
Phosphate (mg/L)	0.268	0.377	0.367	0.332	0.207
Nitrate (mg/L)	11.284	7.355	6.115	6.077	9.159



(a) (b)

Figure 3: Percentage removal correlation between organic substance and nutrient: (a) Organics substance with nitrate (b) Organics substance with phosphate

The organic substance in the microalgae reactor was conducted. COD removal efficiency could attain 50% on the fifth day (Figure 3). However, this condition was highly affected by bacteria-microalgae symbiosis in the system (Ansari et al., 2017). Bacteria in the mixotrophic growth could support organic degradation within the light:dark cycles in the photosynthesis system. The performance of reducing organic substances depends on the wastewater characteristics and the biological process itself. Microalgae in the grey-water system could increase upto to ±70% (Putra and Farahdiba, 2018). However, it could be developed 100% as different microalgae culture and aimed in the biomass production (Selvaratnam et al., 2015), while in the wastewater pilot plant could reach ±90% with CO_2 addition (Posadas et al., 2015). Correlation between COD, N, and P removal efficiency was conducted with statistical analysis. Correlation between COD with N and P, respectively, presents 0.60 and 0.65, which means moderate correlation (Akoglu, 2018). Correlation between COD and DO is strongly negative (-0.92). Increasing organic carbon could enhance algae growth with O_2 production. This O_2 production by microalgae significantly improves O_2 demand of bacteria. Moreover, algae growth could enhance organic removal (Tang et al., 2016). Reducing organic carbon could increase DO, while bacteria could enhance organic degradation based on DO supply in the system.

Conclusion

Microalga with *Chlorella* sp. cultures can reduce organic substance, nitrate and phosphate. Moreover, removal of organic substance in this research work affects nitrate and phosphate removal. The symbiosis between bacteria and algae could be present in the correlation of organic substance and dissolved oxygen. Further research is needed to determine the algae-bacteria symbiosis within the wastewater treatment context.

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