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Influence of *Chlorella vulgaris* Microalgae on the Performance of Membrane Bioreactors for Industrial Wastewater Treatment

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Abstract. This research was conducted to evaluate the Effect of Hydraulic Residence Time and Organic Loading Rate in a Microalgal Membrane Bioreactor for Wastewater Treatment. One method of treating industrial wastewater combines an anoxic procedure with a Moving Bed Biofilm Reactor (MBBR). In this study, process engineering is combined with microalgae to boost dissolved oxygen levels and counteract the rise in sludge. This study combines process engineering with microalgae to mitigate growing sludge and enhance wastewater quality as measured by dissolved oxygen levels. MLSS 1000 mg/L, *Chlorella vulgaris* microalgae 106 L, and 1.75 kg of urea and TSP were the microalgae concentrations utilized. The quality of industrial wastewater is positively impacted by adding microalgae in the MBBR process. The quality of industrial wastewater is positively affected by adding microalgae in the MBBR process. Adding microalgae caused the dissolved oxygen level to rise over the minimal threshold. Additionally, when wastewater is being treated, microalgae might lessen the chance of increasing sludge in the MBBR.

Keywords: *Industrial Waste, MBBR, Microalgae, Dissolved Oxygen, Rising Sludge*

1. Introduction

Due to its hazardous chemical and microbiological contents, wastewater generated by industrial processes can contaminate water supplies. As a result, improper wastewater management significantly negatively influences public and environmental health [1]. Wastewater must be treated to lessen pollutants before being released into aquatic bodies.

Chemical and biological waste are disposed of at wastewater treatment plants (IPAL) [2], [3]. Reducing the amounts of organic and non-organic contaminants in wastewater is the goal of IPAL operations. Several technologies are employed in WWTP, including the Moving Bed Biofilm Reactor (MBBR) [4], Grit Chamber [5], Secondary Clarifier [6], Anoxic Tank [7], and Dissolved Air Flotation (DAF) [8]. Microorganisms or biofilms that develop in the medium

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are used in the biological processing method known as MBBR. The procedure functions optimally because of the enormous surface area of the utilized medium. The benefit of MBBR is that it can lessen nutritional pollutants such as nitrate, nitrite, free ammonia, and COD and BOD pollutants. However, the frequent occurrence of increasing sludge and high electricity consumption when operating the blower are the disadvantages of this MBBR [9].

The combination of an anoxic process and a Moving Bed Biofilm Reactor (MBBR) has been a common technique for treating industrial wastewater in recent years [10]. Nevertheless, the combined process still has drawbacks because it happens gradually, necessitating a lengthy residence period, many piping and supporting devices, and rising sludge. More research must be done to create bioprocess technology engineering properly and efficiently. One benefit of denitrification is rising sludge, typical in activated sludge bioreactors. Because of the high pollution levels that followed this occurrence, particles of activated sludge connected to the developed nitrogen gas bubbles rose to the surface [11], [12]. Increased sludge in the bioreactor process can interfere with the active sludge process' ability to break down wastewater pollutants. It can also cloud the quality of the activated sludge process and lessen its ability to remove contaminants with chemical and biological oxygen demands (COD and BOD) [13], [14].

Furthermore, in the Membrane Bioreactor (MBR), growing sludge frequently causes membrane pores to get blocked [15], [16]. MBR pores have a size of 0.01 – 0.001 m, so they are easily blocked by large particles [17], [18]. The blockage will result in very expensive chemical backwash and MBR cleaning costs. In the past, coagulant and caustic soda chemicals, blower activation, and increased COD and BOD reduction efficiency were used to combat rising sludge levels by lowering TSS (Total Suspended Solids) levels. High electricity usage occurs when the blower is activated to raise the dissolved oxygen value in the MBBR [19]. Then, due to increased mud, adding coagulant agents lowers the TSS value [20], [21]. Nevertheless, including this coagulant raises operating expenses, and using wastewater-neutralizing agents, which try to balance the water left over after the coagulation process, may cause the water's pH to become acidic. Other strategies have also been used to combat the accumulating sludge and boost dissolved oxygen levels to improve COD and BOD reduction performance. Although membrane bioreactors have outstanding TSS rejection values and are highly efficient in reducing TSS, they come with a high investment and maintenance expense [22].

Process engineering with the addition of microalgae in this research is to overcome the increase in sludge and increase dissolved oxygen levels. Microalgae will be utilized in the Microalgae Photo Bioreactor (MPB) system to reduce the occurrence of sludge rise and pore blockages in the Membrane Bioreactor (MBR) in the WWTP unit.

2. Materials and Methods

2.1 Material

A blower, DO meter, MBBR unit, clarifier unit, and nursery tank are used. The materials used were 3000 mg/L of activated sludge and 1000 mg/L of the microalgae species *Chlorella vulgaris*. The ITS Biochemical Technology Laboratory, which helps to provide and cultivate microalgae, is where the microalgae was obtained. Since the ratio of microalgae to activated sludge is microalgae: activated sludge = 1:3, an additional 106 liters of microalgae are required in the MBBR tank, which has a WWTP capacity of 150 m^3/day, with an MLSS concentration of 1000 mg/L and 1.75 kg of urea and TSP each.

2.2 Methods

2.2.1 Microalgae Seeding Stage

500 mg/L of *Chlorella vulgaris* species was added to the nursery tank with dimensions of 17.5 m^3 (2.5m x 2m x 3.5m). Then urea and TSP were added each 1.75 kg. Then seeding occurs until the MLSS (Mixed Liquor Suspended Solids) microalgae concentration reaches 1000 mg/L [23].

2.2.2 Stage of Seeding Microalgae into Active Sludge in MBBR

Seeding microalgae into activated sludge at MBBR is carried out when the MLSS concentration of microalgae at the seeding stage has reached 1000 mg/L. After that, 106 liters of microalgae with an MLSS concentration of 1000 mg/L were added into the bioreactor with a volume of 105.48 m^3 [23].

2.2.3 Experimental Phase of Combining Microalgae with Activated Sludge into the MBBR Tank

At this stage, the dissolved oxygen content in the MBBR is evaluated. Dissolved oxygen is vital in supplying oxygen to activated sludge to degrade pollutants, especially organic substances. Adding microalgae is expected to increase dissolved oxygen above 2 mg/L and improve the performance of reducing rising sludge [23].

2.2.4 Ultrafiltration Membrane Installation

This ultrafiltration membrane is used to prevent washout in microalgae. Using a regular settling system (without an ultrafiltration membrane) will cause a loss of microalgae concentration in the MBBR tank. This membrane is installed when the process pump capacity reaches 5000 L/hour (Q = 5m^3/h x 24 hours = 120m^3/day).

3. Results and Discussion

Rising sludge occurs in the clarifier unit in industrial wastewater treatment. This happens because denitrification takes place excessively, producing much gas or bubbles. The presence of nitrogen gas that enters the activated sludge causes the sludge to become light and rise upwards, resulting in rising sludge. The solution used to overcome the occurrence of rising sludge is by adding microalgae. There were differences in results shown after adding microalgae. The mechanism is that microalgae eat pollutants NO_2^-, NO_3^-, and ammonia (NH_4^+), so the denitrification process does not occur excessively and produces very little gas. Also, microalgae metabolism does not produce gas, so active sludge does not rise to the top, and rising sludge does not occur. The addition of microalgae, which influences the presence or absence of rising sludge in the clarifier unit, will affect the quality of the processed water [24]. Before adding microalgae, the clarifier produces cloudy processed water due to rising sludge. This is different from the addition of microalgae, where in the clarifier unit, no rising sludge occurs so that the resulting outlet water in the holding tank is more transparent, as shown in Figure 1.

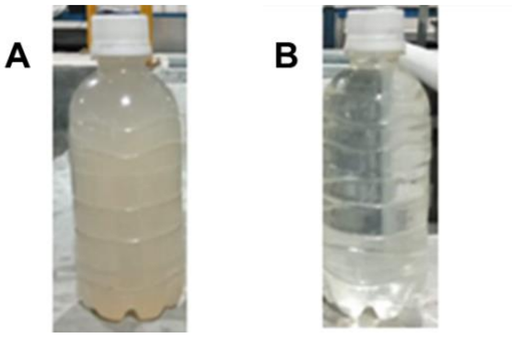

Figure 1. (a) Processed Water Before Adding Microalgae and (b) Processed Water After Adding Microalgae

Several parameters can be used to analyze wastewater quality: DO (Dissolved Oxygen) or dissolved oxygen levels. Dissolved oxygen shows the amount of oxygen needed to oxidize organic compounds dissolved in 1 liter of water. Dissolved oxygen is used as a sign of the degree of impurity in raw water. The greater the dissolved oxygen, the smaller the degree of contamination. The amount of dissolved oxygen in water is a good indicator for determining water quality and life in water [25].

If DO levels are too low, there is a possibility that aerobic organisms will die, and anaerobic organisms will decompose organic matter and produce compounds such as methane (CH_4) and hydrogen sulfide (H_2SO_3). These compounds can cause foul-smelling water. However, low DO levels do not always indicate that there is pollution in the environment. Checking DO levels is one of the parameters in the initial stage of determining water pollution [25].

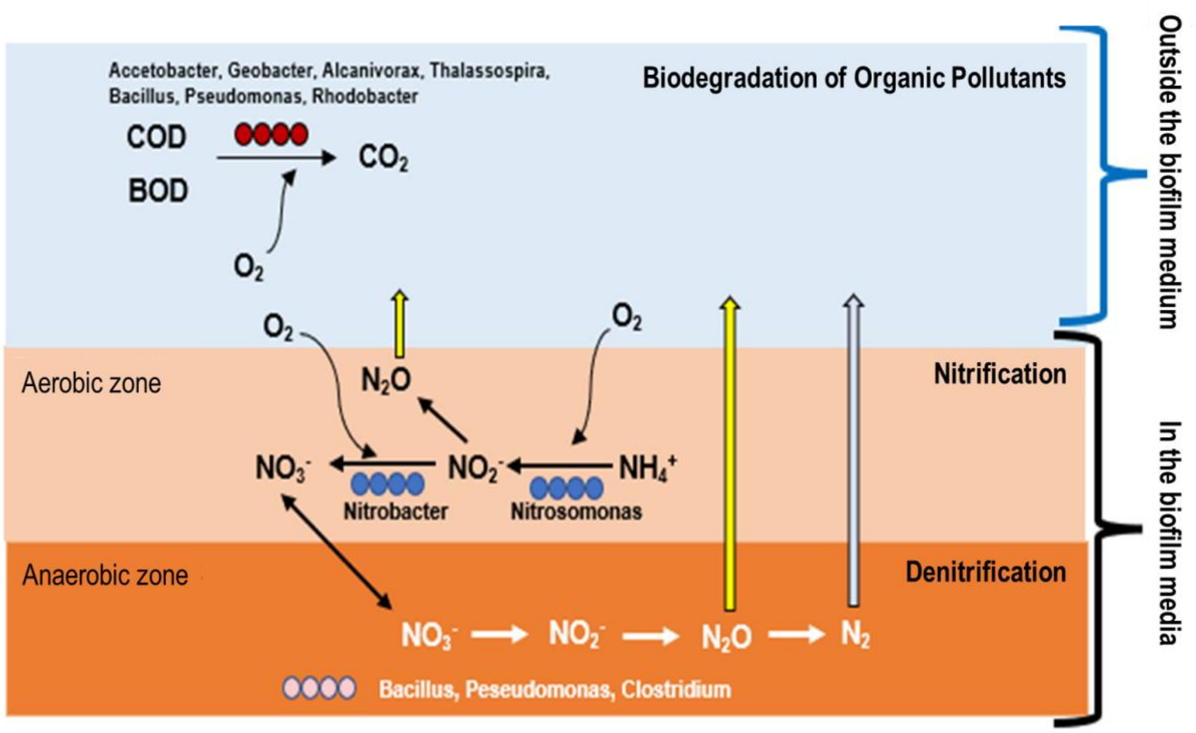

Figure 2. MBBR reaction process (Source: Muharja et al., 2022)

In the MBBR unit, there are three processes for reducing pollutants contained in wastewater, as seen in Figure 2. First, the biodegradation process occurs outside the biofilm media, requiring oxygen (aerobic) to degrade COD and BOD pollutants. Second is nitrification, namely the oxidizing free ammonia (NH_4^+) into nitrite and nitrate with the help of Nitrobacter sp bacteria. and Nitrosomonas sp. [26]. This process takes place aerobically. In the nitrification process, there are two stages, namely the nitridation stage, where the ammonium ion (NH_4^+) is oxidized to nitrite (NO_2^-) with the help of Nitrosomonas bacteria. The stage after nitridation is nitration. Nitration is the process of oxidizing nitrite (NO_2^-) to nitrate (NO_3^-) with the help of Nitrobacter bacteria. Third, denitrification, namely the process of reducing nitrite and nitrate to

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nitrous oxide (N_2O) and nitrogen gas (N_2) with the help of the bacteria Basil sp., Pseudomonas sp., and Clostridium sp. Denitrification is the process of changing nitrate (NO_3^-) into nitrite (NO_2^-), which is then released into nitrogen gas (N_2) with the help of Pseudomonas sp. This process takes place anaerobically [27].

Each process has its advantages and disadvantages. The anaerobic process has the advantage of using low energy because it does not use aeration. However, anaerobic processing has the disadvantage of requiring a long time and slow start-up. Aerobic processing has the advantage of a relatively faster and more effective processing time, but the disadvantage is that it requires a large amount of energy for aeration. While processing using membranes has the advantage that production is stable and the quality of the water produced is good, the disadvantage of processing using membranes is the short time the membrane is used [28].

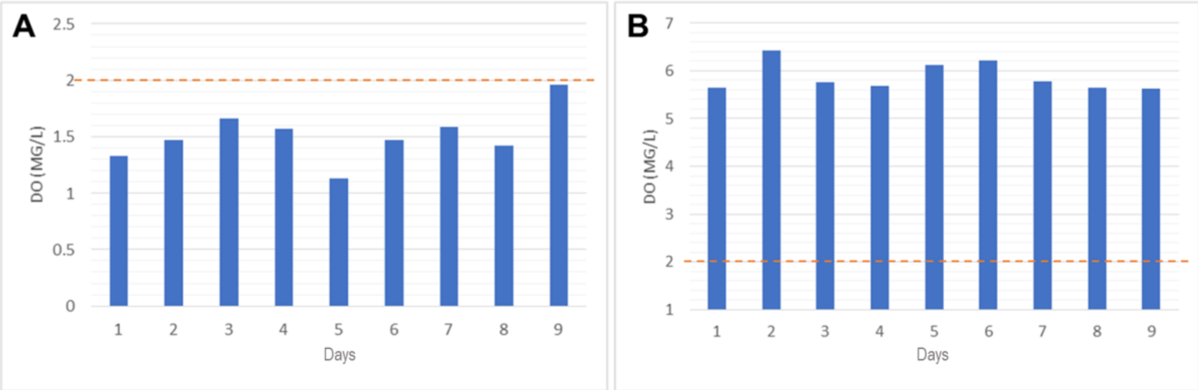

Figure 3. (a) DO levels in wastewater before adding microalgae and (b) DO levels after adding microalgae.

Figure 3 shows the DO levels before (Figure 3(a)) and after (Figure 3(b)) the addition of microalgae. Before adding microalgae, DO levels were below 2 mg/L; after adding microalgae, DO levels were above 2 mg/L. This is because microalgae can photosynthesize and produce oxygen gas, thus helping the efficient performance of microorganisms in activated sludge to degrade organic substances contained in wastewater [29].

Time affects the DO levels obtained because this is related to the growth cycle of microalgae. On day one, there is a delay phase (lag phase), namely the phase where the microalgae adapt to the culture. In this case, adaptation means a mass when the cells lack metabolites and enzymes due to unfavorable circumstances in previous cultivation. In this phase, there is no increase in cell number. On day 2, the microalgae experience an exponential phase where the microalgae experience growth or an increase in cell number. During this phase, cells divide rapidly, are stable, and the number of cells increases at a constant rate. On days 3 and 4, there was a phase of decreasing growth rate. This decline occurs due to high competition in the living medium, and the food substances available in the medium are insufficient to meet the needs of a population that is increasing rapidly in the exponential phase so that only part of the population gets enough nutrition to grow and divide. On days 5 and 6, a stationary phase occurs. In this phase, the number of cells tends to remain constant. This is caused by the exhaustion of nutrients in the media or by the accumulation of toxic metabolic products, causing growth to stop. In most cases, cell turnover occurs in the stationary phase. In this phase, there is a slow loss of cells due to death, balanced by forming new cells through division. If this happens, the number of cells will increase slowly, even though the number of living cells remains the same. On the seventh day, they begin to experience the death phase and cannot survive because they do not receive sufficient nutrient intake, and the air circulation process is not perfect. In this phase, the population number decreases. The number of cells that die per unit of time slowly increases, and finally, the rate of death of the cells becomes constant [30].

Dissolved oxygen in water is used for the respiration needs of aquatic biota in degrading organic materials. Dissolved oxygen generally comes from an ample supply of photosynthesis and aeration. The dissolved oxygen content can decrease due to high water temperatures, the respiration process of aquatic organisms, and the decomposition process of organic material by microbes. Low oxygen content will endanger the aquatic environment because it disrupts the respiratory process in the growth of organisms that live in water [31].

DO is obtained from measurements at the water surface. The depth of the DO measurement also influences the measurement results. This is shown in research by Anggraini et al. (2015), where DO decreased with increasing depth. The decrease in DO occurs due to the decreasing light intensity, inhibiting the continuity of the photosynthesis process [32]. The DO content in water is helpful as a source of oxygen in metabolic processes or organism growth. DO levels will also increase with lower temperatures; conversely, higher temperatures can reduce DO levels [33].

The dissolved oxygen content is influenced by the results of the photosynthesis process of the microalgae *Chlorella* sp., which produces oxygen. Aerobic microorganisms need dissolved oxygen to oxidize organic and inorganic materials. The more dissolved oxygen content, the better the water quality [34]. Ayuzar et al. (2022) said that if the dissolved oxygen (DO) level is around 3-5 mg/L, then the growth of microalgae is less productive, whereas if the

DO level is around 5-7 mg/L, the productivity of the microalgae is high and if the DO level is above 7 mg/L the productivity of the microalgae very high [35]. So, it can be seen that in this study, the productivity of microalgae was relatively high.

Several factors influence the growth of microalgae and their productivity in waste processing. First, adding nutrients such as nitrogen and phosphorus can be obtained from organic waste. Second, good environmental conditions must be maintained so that microalgae can grow optimally. Third, population density must be considered so that it is not too dense, which will cause microalgae to lack nutrition due to competition due to an unbalanced ratio between the number of microalgae and the available nutrients. Fourth, regular water changes can remove waste and replace it with fresher nutrients. Based on the factors described above, the DO levels obtained are classified as high or not very high, possibly due to environmental conditions less supportive of achieving DO levels above 7 mg/L. The amount of microalgae and activated sludge used in a ratio of 1:3 is considered ideal because it can optimize the growth of microalgae and the ability of activated sludge to remove organic nutrients. This comparison is sufficient to produce DO levels in the processed water that can be said to be high. Meanwhile, if you want to get DO levels above 7 mg/L, you need to pay attention to environmental conditions so that they match what microalgae need to reproduce [35].

4. Conclusion

This research succeeded in answering problems that often occur in wastewater treatment in industry. Adding microalgae in the MBBR process positively impacts the quality of industrial wastewater. The dissolved oxygen content increased beyond the minimum threshold due to adding microalgae. Microalgae can also reduce the risk of rising sludge in the MBBR during wastewater treatment. Alternative uses of microalgae in processing systems are worthy of further development, considering the several advantages shown during research.

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