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Acetogenic Removal Efficiency of POME Under the Influence of Electromagnetic Field

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Abstract. Palm oil mill effluent (POME) is categorized as high strength wastewater. The current treatment technology for POME is mostly depends on biological treatment through anaerobic and aerobic processes. Application of magnetic field was reported able to show effective removal performance of pollutant. The exposure of magnetic field will cause changes on the physical and chemical properties on a molecular level. The main objective of this research is to evaluate the application of EMF to enhance the performance of acetogenic microbes towards POME treatment. In this study, the EMF was evaluated in batch reactor system under an anaerobic acetogenic condition followed by aerobic reaction phase to treat POME. The hydraulic retention time and the intensity of EMF applied in this study were five days and ±15 mT respectively. The results indicated that using EMF improves the removal performance of color by 19%, chemical oxygen demand (COD) by 28%, ammonia nitrogen by 13%, nitrite by 17% and nitrate by 31%. Ultimately, the application of EMF helps to enhance anaerobic acetogenic bacteria and then enhanced the overall removal performance.

1. Introduction

Over the last few decades, the palm oil industry has grown significantly in Malaysia and has become one of its major industries. However, the producing palm oil has several environmental impacts that should not be neglected. One of such environmental effects is the pollution that is caused from palm oil mill effluents (henceforth referred to as POME) [1]. POME is characterized with high in organic content with average values of 25,000 mg/L biochemical oxygen demand (BOD) and 50,000 mg/L COD, 18 000 mg/L, 40500 mg/L total solid (TS) and 4000mg/L oil and grease [2]. The high number degree of BOD and COD makes it very difficult to dispose of POME, since by discharging it into waterways, it can lead to massive environmental damage and pollution [3]. Thus, an efficient and effective treatment system should be applied in order to prevent the adverse impact that may take place if the improper treated POME is release to the water bodies.

2. Literature review

The conventional treatment of POME adopted by most palm oil mills in Malaysia usually consists of anaerobic process followed by an aerobic process [4]. This system often uses the ponding system, which has several drawbacks such as long retention times, which leads to the need for larger treatment areas to hold the POME while it's being treated [5]. Many approaches have been used to treat POME such as coagulation, adsorption, oxidation, and membrane. However, most of these methods have their own disadvantages. For instance, coagulation/flocculation process cannot apply alone and generally are being used as a pre-treatment for further treatment process and requires a very high amount of chemicals [6]. Adsorption process has a predicament concerning needing a post-treatment [7]. Meanwhile, oxidation process has a restriction regarding high operating cost [8]. Membrane approach has a barrier in dealing with excessive suspended solids effluent and commonly suffer from clogging [9]. Thus, there is an actual need to identify the factors intensifying the processes of pollutant degradation or an alternative assistive method for POME treatment.

The use of a magnetic field is considered to be among the top solutions used for wastewater treatment when it comes to the physical factors [10]. Decades of research indicate that the contaminated waters physical and chemical properties can both be influenced via the use of magnetic fields [11]. Some of the affected properties are the changes that occur in the molecular structure of the wastewater liquids. The electric potential also undergoes some changes with the use of magnetism, which consequently affects the polarization and arrangement of the particles inside the liquid [12].

A few studies have been done to explore the effect of magnetic technology on activated sludge process regardless of them being on microbes or on pollutant. With regards to the effects of magnetic field on microbes, previous study by Ji et al. [13] demonstrated that a 20 mT magnetic field induction could have positive effects on bacterial growth in activated sludge. In older research by Okuno et al. [14] and later confirmed by Rao et al. [15], it was discovered that microbe's growth rate has a relationship with the magnetic field, and it can either accelerate or decelerate the process. Łebkowska et al. [16] found that magnetic field could stimulate the growth of sludge biomass, and subsequently increase the number of bacteria and microfauna in the activated sludge. Wang et al. [17] proved that an intensity of 48 mT static magnetic field was beneficial to the growth the activity nitrite-oxidizing bacteria. Liu et al. [18] found that 75mT static magnetic field could enhance anaerobic ammonium oxidation (anammox) activity.

In terms of pollutants degradation using magnetic technology, Jung et al. [19] showed that the efficiency of phenol biodegradation rate increased to 30% by applying a magnetic field of 450 mT as compared to the control system. Łebkowska et al. [16] found that a static magnetic field of 7 mT could enhance formaldehyde biodegradation and decrease in COD concentration by higher 30% and 26% respectively, in comparison with the control. While Liu et al. [18] found a maximum 50% increase in nitrogen removal at the value of 75 mT. These investigations indicated that the application of magnetic field on activated sludge could enhance the growth of microbes and also improve the removal efficiencies of some pollutants.

Based on the mentioned research, it can be concluded that biological treatment via the use of magnetic field is effective. However, previous research is mostly concentrated on synthetic wastewater which was only conducted in the laboratory [17,20].

Currently, there are very few research that focus on the effect of magnetic field for POME treatment. Thus, the main objective of this research is to evaluate the utility of electromagnetic magnetic field towards enhancing the performance of acetogenic microbes towards POME treatment.

3. Methodology

The POME samples collected from an anaerobic pond of the palm oil industry in Felda Kulai, Johor, Malaysia. The samples were sieved using a 1.0 mm mesh to remove large debris and inert impurities, and then stored at 4 °C prior to experimental work. Anaerobic sludge is used as the source of sludge biomass that was taken from the palm oil mill. The experimental work was conducted in a 2 L glass column with a working volume of 2 L. In the batch experiments, two reactors were used in parallel. One was equipped with magnetic field facilities (A) and the other one was the reference (B). Aluminum foils were used to cover the columns to provide anaerobic condition as shown in Figure 1.

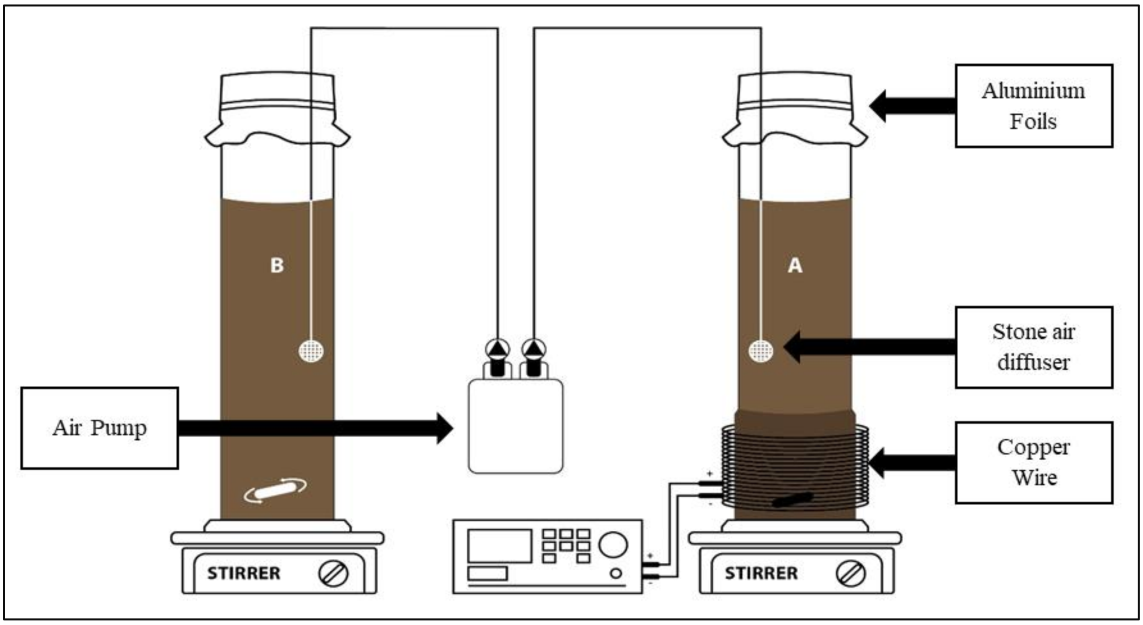

Figure 1. Schematic layout of the two column-type batch in this study

In this study, five days HRT was used to evaluate the effect of anaerobic acetogenic condition on degradation of organic matters in POME. The initial mixed liquor suspended solid (MLSS) concentration was 2,000 mg/L. In order to assure a well-mixed condition of the biomass and the wastewater, the wastewater was mixed throughout the experimental work using a magnetic stirrer rotated at 50 rpm. The volumetric exchange rate of the system was set at 50% and the pH was adjusted to 6.8-6.5 using 2N hydrochloric acid (HCL) and 1 N sodium hydroxide (NaOH).

The reactors were purged once on a daily basis by adjusting the dissolved oxygen concentration to 2.0 mg/L. Aeration was conducted using an air pump with a superficial air velocity of 0.5 cm/s. To increase dissolved oxygen concentration to 2.0 mg/L, short oxygen purging time is used (3-5) minutes. One of the reactors was modified to apply magnetic field by surrounding the reactor with a solenoid of 1.5 mm copper wire. Magnetic field was applied by using an AC power supply.

For the first six cycles, EMF was imposed on daily bases for 1hr. Then time of EMF imposing increased to 3hrs till the end of the experiment. The treatment system was operated under room temperature. The properties of fed samples were examined every five days. HORIBA/pH/DO meter model was used in order to measure the POME pH/DO level.

The final effluent was centrifuged for 15 min at 6,000 rpm to separate the liquid and solid phases for further analysis. The sample was then analyzed for COD, color, ammonia nitrogen, nitrate, and nitrite. The parameters were carried out according to Standard Methods for the Examination of Water and Wastewater [21]. The analytical tests followed the procedures as given in the Hach Water Analysis Handbook [22].

4. Results and findings

POME samples collected from the anaerobic pond were characterized in Table 1.

Table1. Summary of essential characteristics of POME

Parameters	Value
COD mg/L	1240
Color ADMI	1244
NH_3N mg/L	258
Nitrate mg/L	20
Nitrite mg/L	79

In anaerobic acetogenic process, the anaerobic reaction is manipulated to enhance the acetogenic process by limiting the methanogenic process. The inhibition of methanogenic process limits the reaction to acetogenesis and eliminates the emission of methane, which is a greenhouse gas [23].

The preferred pH for the acetogenic stage is somewhere between 5 and 6. For the methanogenic process, the preferred pH value is 7 [5]. Due to the sensitivity of the methanogens to pH below 7, in acetogenic environments the methanogens are rarely present [24]. Unlike the methanogens, the acetogenic microbes do not suffer from the same sensitivity, and thus are able to survive in methanogenic neutral pH environment [24]. Thus, the pH was adjusted to 6.8-6.5 in order to ensure the successful development of anaerobic acetogenic digestion condition [25].

To improve the performance of the acetogenic microbial growth, air can be injected into the reactor. Since these organisms are facultative, they do not require large amounts of oxygen to matabolize organic matters. However, the methanogenic microbes have a negative reaction to oxygen, and thus with the injection of air into the reactor, the acetogenic microbes should thrive, while the methanogenic microbes would be eliminated [26,27].

Damayanti et al. [24] stated that air purging reduced volatile fatty acid VFA production. However, the expectation was for the VFA accumulation to increase due to the air injection. One of the possibilities as to why this did not happen, can be due to the methanogenic microbes consuming the VFA for the purposes of self-maintenance as the air is injected into the reactor. Even though the conversion rate of COD to VFA is relatively high, the existence of these methanogenic microbes, ensures that no VFA is accumulated. As the oxygen in the air is injected into the reactor, these microbes will perceive the environment as toxic, and dangerous. Thus, to survive they pre-emptively consume the VFA without the biogas production.

The anaerobic acetogenic reactors were operated for 14 cycles (70) days. The performance of the experiment was determined on the basis of COD, color, ammonia nitrogen, nitrite and nitrate removal. At the beginning of the experiment, COD removal was 42% in reactor A and 53% in reactor B which then increased to 55% in reactor A and slightly decreased to 47% in reactor B at cycle 6 as shown in Figure 2. However, the removals for reactor A and reactor B were not much vary. This could imply that EMF imposing time for 1hr daily was not enough to enhance COD degradation.

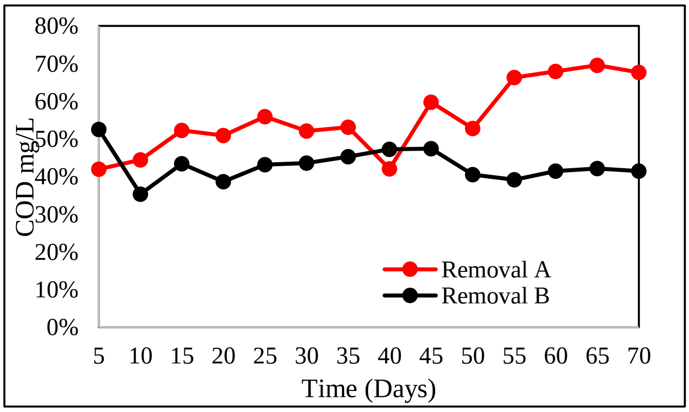

Figure 2. Percentage removal of COD

The works of other authors using magnetic field showed that magnetic field is an intensifying factor for organic substrate degradation [13,28,29]. Moreover, magnetic field may be influenced by exposure time [13,30,31]. Thus, rather than increasing intensity, the imposing time increased to 3 hrs. The effect of EMF showed an increase in COD removal compares to control system. The removal efficiency increased to over 69% in reactor A while decreased slightly to 41% in reactor B at the end of experiment. The increase in the removal efficiency in reactor A indicates the occurrence of high biological activity in the reactor system.

The removal percentage of color depends on microbial ability, either to consume color causing compounds such as lignin or to produce biological products such as enzymes to remove color [32]. Based on Figure 3, color removal percentage was 44% in reactor A while the percentage of color removal was low 28% in reactor B in the first 30th days of experiment. However, after the 30th days improvement in color removal was observed in both reactors. A significant improvement in color removal from 44% to 62% was observed for reactor A. However, color removal in reactor B increased from 28% to 43%.

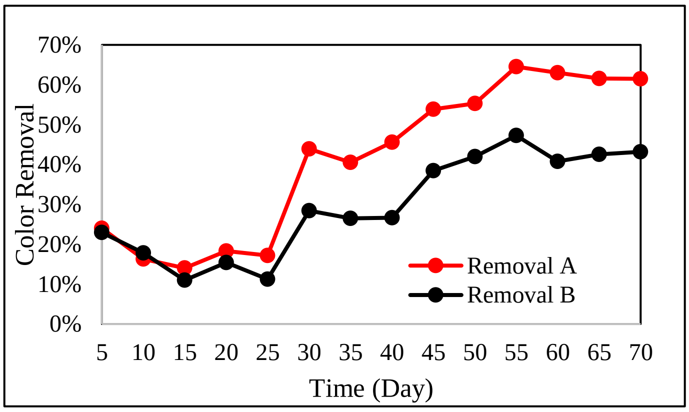

Figure 3. Percentage removal of Color

There were three components of nitrogen that been analysed ammonia nitrogen, nitrite and nitrate. The performance of the removals/productions, the respective influent and effluent of nitrite and nitrate for reactor A and reactor B. Reactor A exhibited good performance of autotrophic nitrogen removal for POME compared to reactor B (control system).

The trend of ammonia nitrogen removal is also depicted in Figure 4. At the end of experiment the average removal performance was 53% and 40% for reactor A and B respectively. The findings suggested that the magnetic field may have potential in enhancing the activities of ammonium oxidizing bacteria (AOB) that is known to be responsible in the ammonia oxidation and nitrification process. Tomska et al. [28] and Wang et al. [17] were also agreed that the ammonia oxidation rate of activated sludge exposed to the magnetic field was higher than the control system.

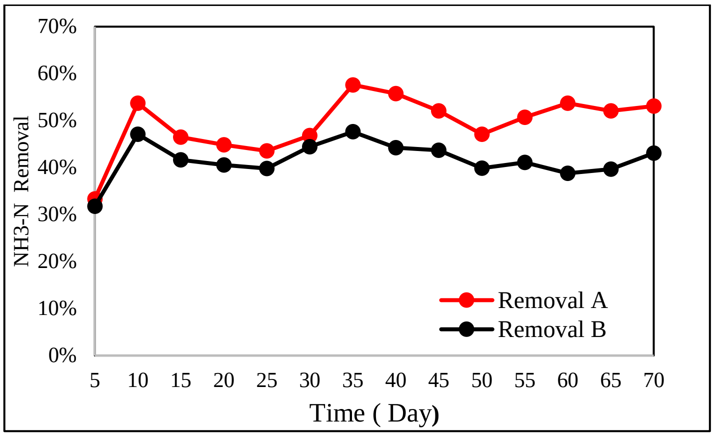

Figure 4. Percentage removal of NH3-N

During start-up, the percentage removal of nitrite was low in both reactors. The removal performance, however, starts to improve by showing gradually increased to above 92% reactors A as shown in Figure 5. Meanwhile, the nitrite removal in reactor B was only about 76%. Such observation between reactor A and reactor B can be reasoned due to the possibility of magnetic field that could improve the growth of microbial cells such as nitrite-oxidizing bacteria through increasing the transport of oxygen and nutrients to the cells [17,33]. The improvement of the microbial cells might then enhance the oxidizing activities. This resulted in better performance of the nitrite removal in reactor A compared to reactor B.

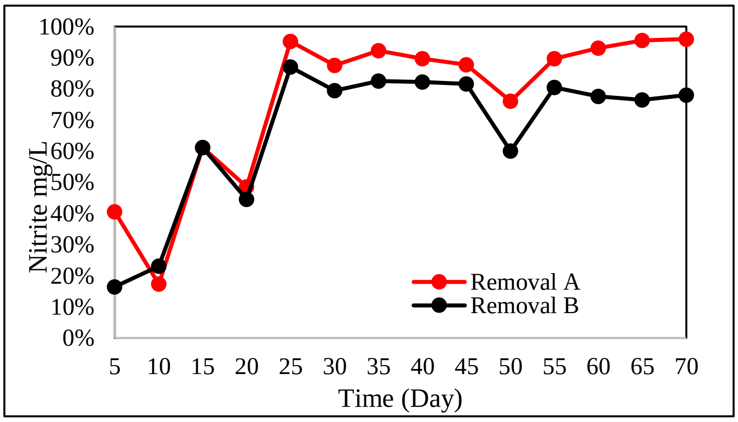

Figure 5. Percentage removal of Nitrite

One of the nitrogen components which is nitrate showed a production trend instead of removal at the end of experiment as shown in Figure 6. The nitrate removal for A and B reactors reached the steady state at day 35 until day 45 with average removal 95% and 88% respectively. However, at day 55 both reactors showed production trend instead of removal. This means that more nitrate was presence in effluent compared to in influent. Based on Figure 6 the nitrate production remained low for reactor A with average production 11% compared with 19% for reactor B. However, severe fluctuation in nitrate production was shown in reactor B suggesting that nitrification-denitrification process was inconsistent.

During the process of nitrogen removal, ammonia was converted to nitrite and then to nitrate (nitrification) in the presence of oxygen. Subsequently, nitrate was reduced to nitrogen and/or nitrogen oxide (denitrification) in the absence of oxygen [34,35]. As in this case, denitrification was failed to occur effectively especially in reactor B. Supposedly, the denitrification should take place when the DO concentration is lowering. However, in reactor A the application of magnetic field may help in resulting low effluent nitrate despite the failure of denitrification process [16,17].

For this experiment, the system was running under acetogenic condition which oxygen is purged for a few minutes only. However, aerobic condition for 24hrs is served to the system as a polishing phase. Still, further investigation needs to be conducted in order to improve the stability of the system performances for the removal of nitrate.

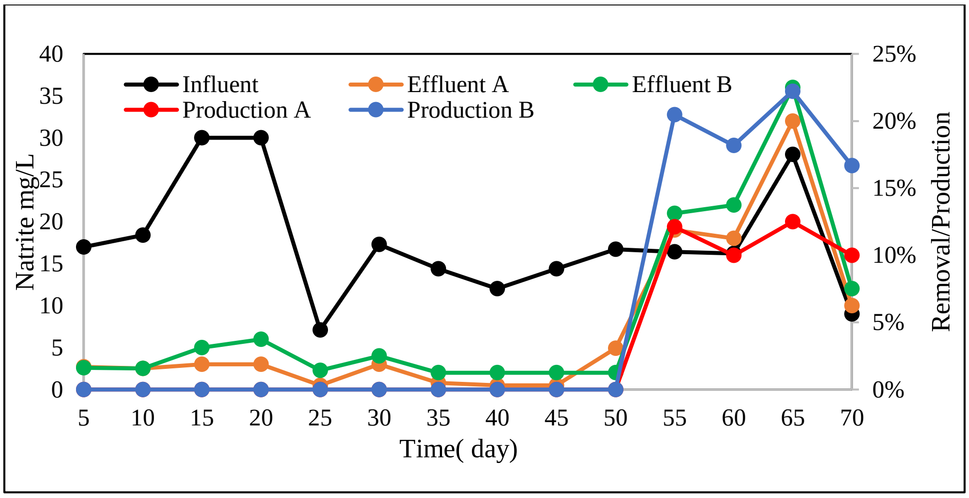

Figure 6. Percentage removal of Nitrate

5. Conclusion

The induction of EMF was more effective in treating POME under acetogenic condition than that of control system without EMF. Batch experiment was successfully operated for 70 days under acetogenesis condition with assets of EMF imposing to enhance removal efficiency. It was observed that the use of EMF could improve the treatment system. Resulting high removal performance of color, COD, ammonia nitrogen, nitrite and nitrate. Acetogenesis combined with EMF is introduced as an environmentally friendly process to treat high pollutant wastewater such as POME and reduced the effect of biogas emission.

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