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Full paper

Treatment of Aerobic Treated Palm Oil Mill Effluent (AT-POME) by using TiO_2 Photocatalytic Process

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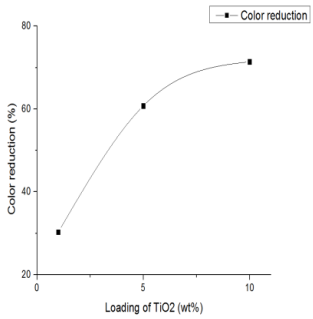
Graphical abstract



Abstract

Palm oil mill effluent (POME) is one of the major wastewater sources found in Malaysia. Despite the reduction of biochemical oxygen demand (BOD) through aerobic or anaerobic biodegradation, the effluent of the treated wastewater (AT-POME) remains dark owing to the degradation of lignocellulosic from the raw POME. In this study, photocatalyst, TiO_2 was used to degrade the color pigment that presence in the AT-POME. Besides, different loadings of TiO_2 were used to investigate the effect of catalyst loading towards the photodegradation efficiency. The results showed that 10 wt% of TiO_2 can remove more than 70% of the color pigment in AT-POME. However, the color reduction only increased slightly when the loading increased from 5 wt% to 10 wt%. This phenomenon occured due to the agglomeration of nanoparticles in the suspension and the excessive of photocatalyst in the suspension that have prevented the penetration of UV irradiation and consequently slowed down the photodegradation.

Keywords: Advance oxidation processes; palm oil mill effluent; photocatalyst; titanium dioxide

1.0 INTRODUCTION

The application of palm oil in food and non-food industry has accelerated of palm oil industry development in Southeast Asia, especially Indonesia and Malaysia. However, the extraction process of palm oil consumes a lot of process water which will end up with palm oil mill effluent (POME). POME is a brown colloidal solution with high suspended solid contents and produce unpleasant smell. It has been identified as one of the pollutants to the source water. Therefore, efforts have been focused to investigate the feasible approaches to treat the POME prior to its discharge to water source. Theoretically, POME does not contain any hazardous compounds that harmful to the environment. However, when POME is discharged directly without treatment, its high organic content will undesirably lead to eutrophication effect that might be activated by the algae in the source water.

Currently, POME is treated by bio-degradation method (i.e. aerobic digestion and anaerobic digestion). Bio-degradation is a treatment method that utilizing microorganism that consume organic compound in the POME as their respiration substrate and enable to breakdown them into simpler component. However, there are several drawback of this bio-degradation method. First, the production of unpleasant smell (especially anaerobic digestion) is unfavourable to the public and will cause a bad working environment [1-3]. Secondly, the long retention time of the bio-degradation is another factor that requires the huge ponding area for proper treatment or stage-by stage treatment. Besides, the sensitivity of the microorganism towards the environmental changes is another issue for the proper degradation of the POME. But, the advantages of the biological treatment such as low cost of production, generation of side product such as methane gas via anaerobic digestion have prompted this approach to be widely applied by the industry [2, 4].

There are several researchers suggested that employment of integrated process such as membrane bioreactor for the polishing of the effluent from the biological treated POME. Besides, the utilization of the membrane system in the biodegradation plant has enable the catchment and storage of the syn-gas (i.e. methane gas) for the boiler or plant application [5]. However, the color of the effluent from the treatment plant remains dark in nature. This prompt another issue as public acceptance to this dark color effluent is low owing to the safety of the effluent although it is proven that the effluent had reached the discharge limit of the government. Hence, the alternative is seek for the decolorization of

the effluent. Some of the researchers suggested that the dark color of the effluent can be attributed to the breakdown of lignocellulosic from the raw POME into lignin and tannin [6-7].

Accordingly, researchers have attempted adsorption method for the decolorization of treated POME so that the color and organic substances can be adsorbed and further improve the quality of the biodegraded effluents. Activated carbon and banana peel have been employed as the bio-sorbent for the adsorption process [7]. The bio-sorbent seemed to be a promising alternative for the color reduction. Besides, pre-treatment of the bio-sorbent in acidic or alkaline condition has increased their capability in the adsorption process. However, the utilization of bio-sorbent has produced a lot of solid waste that need to be treated by additional process i.e. chemical process for desorption.

Advance oxidation processes (AOPs) is an alternative that enables the degradation of organic compound in the wastewater through a redox reaction of the compound via certain condition. AOPs have attracted a lot of interest to explore their capability in various types of wastewater treatments. However, utilization of photocatalyst in the system will cause the difficulty in the product purification stage. Generally, the catalyst can be revocered by separation process such as membrane filtration. But, there are some researchers starts to embed the catalyst onto a support surface, i.e. polymer for the elimination of separation process at the end of bio-degradation [8-9]. In this context, coating or embedment of catalyst onto certain support such as polymer surface has one big challenge, which is the leaching problem. Therefore, scientist nowadays using ultrafiltration after the AOPs suspension system for the recovery of catalyst and also obtaining good quality of effluent.

In this study, photocatalyst, i.e. TiO_2 was used to degrade the color pigment that present in AT-POME under the illumination of UVB. The COD, TOC and color removal characterizations were carried out to determine the efficiency of the photocatalysis of the TiO_2 towards AT-POME. Hence, the different loading of TiO_2 (i.e. 1 wt% to 10 wt%) was carried out to study the effect of catalyst loading to the photodegradation.

■2.0 EXPERIMENTAL

2.1 Materials

TiO2 nanoparticles (Degussa P25, average particle size ~21 nm) was purchased from Evonik were used as photocatalyst in this experiment.

2.2 POME Sampling

The AT-POME was collected from Jugra Palm Oil Mill, Banting, Selangor, Malaysia. The AT-POME was used to rinse the sampling bottle. After that, AT-POME was filled until full of the sampling bottle. The collected sample was subjected to a series of prefiltration (i.e. 5µm, 2µm and 0.45µm) to eliminate all the suspended solids. The resulted pre-treated AT-POME was kept into 4°C refrigerator before membrane separation process. The characteristics of AT- POME are shown in Table 1.

Table 1 Characteristics of AT-POME

Parameter	Unit	Value
Odor	N/A	No
Total organic carbon (TOC)	ppm	724.75 ± 2.45
Total nitrogen (TN)	ppm	88.27 ± 6.03
Biochemical oxygen demand (BOD)	ppm	21.95
Chemical oxygen demand (COD)	ppm	527.33 ± 12.22
Color (at wavelength of 349 nm)	abs	6.582 ± 0.032

2.3 Experiment Setup

The 250 mL of AT-POME was mixed with photocatalyst, i.e. TiO_2 in a beaker. The mixture was then put onto the magnetic stirrer and stired at a speed of 250 rpm for 4 hours. The setup was placed in a stainless steel cupboard with UVB irradiation. The setup of experiment was shown in Figure 1. The 50 +mL sample was collected before and after the illumination of UVB and centrifuge at 4000 rpm for 10 minutes. The supernatant was analysed via COD, TOC and color with standard method.

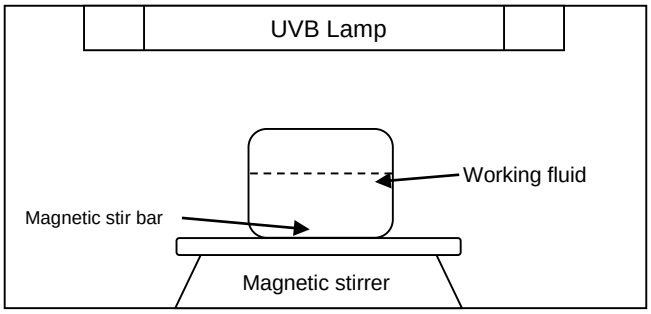


Figure 1 Experimental setup of photocatalysis

2.3 Analysis

2.3.1 Chemical oxygen demand (COD)

The COD analysis was carried out according to the USEPA procedure. The testing reagent and equipment (MODEL) were purchased from HACH Company. 2 mL of centrifuged sample was pipetted into the testing vial with reagent and placed into the DBR 200 reactor for 2 hours and the COD reading was identified by using DR5000 Spectrophotometer.

2.3.2 Total Organic Carbon

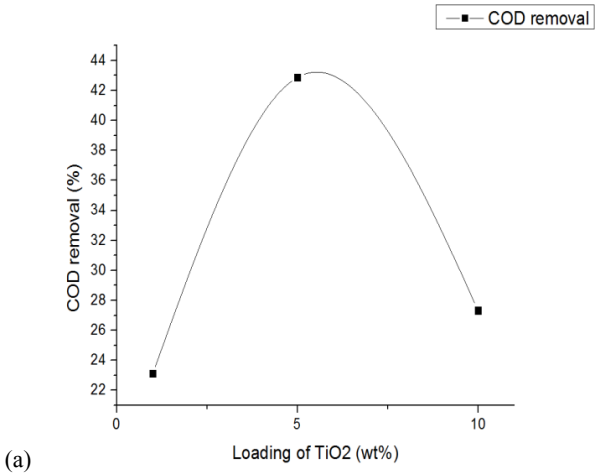
The TOC analysis was carried out according to USEPA procedure. The centrifuged sample was analysed by using Shimadzu TOC-LCPN. TOC was calculated based on the difference between total carbon and total inorganic carbon in the sample.

2.3.3 Color

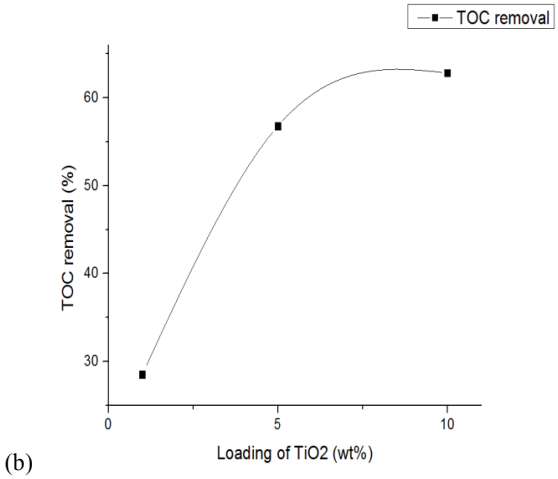
Color analysis was carried out by using DR5000 Spectrophotometer, HACH Company. Before the treatment, the sample was scanned through a series of wavelength and the peak absorbance was found out at 349 nm. After the treatment, the centrifuged sample was scanned at 349 nm and the absorbance was recorded.

■3.0 RESULTS AND DISCUSSION

This study focused on the effect of TiO_2, ranging from 1-10wt%, on the photodegradation of color pigment that present in AT-POME. Figure 2 shows the effect of photocatalyst loading on its degradation efficiency.



(a)



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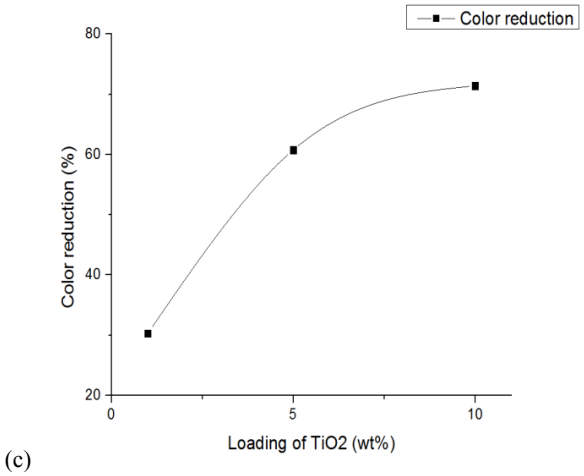

(c)

Figure 2 Removal efficiency on (a) COD reduction, (b) TOC reduction and (c) Color reduction of AT-POME

From the results obtained, the increase in the catalyst loading has increased the photodegradation activity. The increment of the loading of catalyst increased the active sites on the photocatalyst surface, hence, the photoexcitation occured at higher rate. As a result, the number of photoexcited holes and electrons increased [10]. This increment enabled the fast generation of hydroxyl and superoxide radicals. Therefore, the photodegradation activity increased and resulted in the increase of COD, TOC and color removal. However, from Figure 2, it can be noticed that the increment of TiO_2 loading from 1 wt% to 5 wt% resulted in a huge reduction of COD, TOC and color reduction. However, when the loading was further increased to 10 wt%, the removal efficiency was not so favourable. This phenomenon might due to the further increase of catalyst loading has led to the agglomeration of the catalyst and subsequently reduced the number of active site in the suspension. Hence, the removal efficiency only increased slightly. Besides, there are some researchers reported that the further increase of catalyst beyond the optimum point tends to increase the turbitidy of the suspension. This caused the illumination of UVB into the suspension become difficult. As a result, the number of catalyst that capable to be photoexcited decrease and lead to the slightly increase of removal efficiency from 5 wt% loading to 10 wt% loading.

4.0 CONCLUSION

This study focused on the effect of TiO_2 on the decolorization of AT-POME. There are several conclusions can be drawn from the observation:

i. The increment of the catalyst loading increased the reduction of COD, TOC and color absorbance at 349nm.
ii. Increment of TiO_2 from 5 wt% to 10 wt% did not significant improve the color reduction much owing to the agglomeration of the catalyst in the suspension.
iii. Photocatalysis process can be applied for the color removal in AT-POME treatment.

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