CHAPTER 6

PHOTOCATALYTIC DEGRADATION OF PALM OIL MILL SECONDARY EFFLUENT

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6.1 INTRODUCTION

Palm oil industry is one of the industries that has major disposal problem in disposing the lignocelluloic biomass such as oil palm trunks (OPT), oil palm fronds (OPF), empty fruits bunches (EFB) and palm pressed fibres (PPF), palm shells and palm oil mill effluent (POME) [1]. Amongst all waste produced, POME is the most difficult waste to treat due to its high volume generated [2]. POME consists of 95-96% water, 0.6-0.7% of oil and 4-5% and total solid. Although it was said that POME is nontoxic, however the abundance of POME in water stream could lead to oxygen depletion in water stream as POME contains high amount of nitrogen (N), phosphorous (P), potassium (K), magnesium (Mg), and calcium (Ca) which later on could lead to plant growth in aquatic region. POME also consists of sterilizer condensate, separator sludge and hydrocyclone (DOE 1999). The treatment of POME generally undergo ponding system, open tank digester and extended aeration system, or closed anaerobic digester and land application system. Palm oil mill secondary effluent (POMSE) is the result of treatment of POME and is characterized by having a thick, brownish color and bad odor wastewater. Although POME was claimed to be treated with one of the systems, several studies showed that the POMSE still exceed the standard discharge limit set by both
Therefore, the treatment of POMSE is very important because the concentration of pollution and organic contained could affect the stream and posed some hazard to the aquatic communities, environment and also human health. One of the alternative treatment method that can be implemented to treat and remove various organic impurities in POMSE is photocatalytic degradation process due to its advantages including ease of setup and operation at ambient temperatures, no need for postprocesses, low consumption of energy and consequently low cost [3]. In photocatalysis process, the photocatalyst generates electron hole pairs with free electrons produced in the empty conduction band leaving positive holes in the valence band which played a significant role in photodegradation of dye molecules [4].

Nanoparticles are known as one of the good photocatalysts for the degradation of wastewater. It was reported that nanotechnology offers the detection and an efficient removal of chemical and biological substances include pollutants and germs in the area of water purification [5]. Nanoparticles are attracting a great attention from biological, agricultural and pharmaceutical industries due to their structures that have high specific surface areas, potential for achieving specific processes and selectivity, high photosensitivity, stability and large band gap. Zinc oxide (ZnO) is one of the nanoparticles that is believed can purify water or treat wastewater due to its characteristics such as effective wastewater purification method due to its efficacy in decomposing and mineralizing the hazardous organic pollutants as well as the good adsorption of ultraviolet (UV) light [6].

Recently, Desa (2017) revealed that zinc oxide (ZnO) nanoparticles in presence of polyvinylprrolidone (PVP) has high potential for photocatalytic degradation of industrial dye wastewater. However, the potential of ZnO-PVP in treating POMSE is not been concealed. The characteristic of ZnO-PVP nanoparticles as well as the optimum condition of photocatalytic degradation in presence of ZnO-PVP for POMSE treatment with the analysis of also not been well discovered. Therefore in this study, the characteristic of ZnO-PVP nanoparticles has been examined in order to observe their purity, crystallinity, properties of chemical bonding and its nature. Consequently, the optimum condition of photocatalytic degradation of POMSE in presence of ZnO-PVP nanoparticles with their analysis will also be identified.

6.2 CHARACTERIZATION OF ZNO-PVP NANOPARTICLES

X-Ray Diffractometry (XRD) and Fourier Transform Infrared Spectroscopy (FTIR) analysis have been carried out in order to study the physical and chemical properties of ZnO-PVP nanoparticles. The purity and crystallinity of ZnO-PVP nanoparticles have been determined through XRD pattern analysis. X-Ray Diffractometry (XRD) (Bruker AXS GmbH model) have been used in this project using the Cu Kα radiation with λ=1.5418Å at 40 kV and 40 mA. The data have been collected at room temperature over the range of 2θ=2°-90° with a scan rate of 0.025° continuously [7]. The analysis has been conducted at Makmal Sumber, Faculty of Mechanical Engineering and Manufacturing (FKMP) in University of Tun Hussein Onn Malaysia (UTHM).
The properties of chemical bonds and nature of ZnO-PVP have been analyzed by FTIR that produce infrared absorption spectrum. FTIR results have been recorded using Perkin-Elmer FTIR Spectrum RX-I spectrophotometer (Nicolet T-IR Avatar 360) in the wavelength range 400-6000 cm\(^{-1}\). The analysis has been conducted at Ceramic Laboratory, FKMP, UTHM.

### 6.3 OPTIMIZATION OF POMSE TREATMENT (DESIGN OF EXPERIMENT)

The optimization of photocatalytic degradation of POMSE using ZnO-PVP nanoparticles under UV light irradiation was conducted. The correlation of the pH of POMSE, amount of ZnO-PVP nanoparticles and concentration of POMSE was optimized by response surface method (RSM) using a second order polynomial model with central composite design consists of 9 runs as shown in Fig. 3.1. In this study, the pH of POMSE was varied from 4.0 to 9.0 while amount of ZnO-PVP nanoparticles was varied between ranges 0.08 g/L to 0.90 g/l. Moreover, the concentration was varied between 0.25 to 1.00.

![Figure 6.1: Table of RSM.](image)

### 6.4 PHOTOCATALYTIC DEGRADATION PROCESS

![Figure 6.2: Experimental set up of photocatalytic degradation process.](image)

In this study, 1 litre of conical flask has been used as the photocatalytic reactor in batch method. The photocatalysis process was conducted under UV lamp (253.7nm, 18 W, GPH295T5L 4PSE, USA) for activation of the photocatalyst. Then, ZnO-PVP nanoparticles was added into the reactor that is filled with 500 mL of POMSE sample.
The mixture has been agitated well by magnetic stirrer at 150 rpm under room temperature (25°C). The operation temperature will be controlled by recirculation of water in a water bath. The schematic diagram of photocatalysis process was illustrated in Fig. 3.2.

Sodium hydroxide (NaOH) and sodium chloride (NaCl) (purchased from R&M Marketing, Essex, UK) were used for pH adjustment of the solution. The pH value has been measured by pH meter (pH 1500, EUTECH instruments). At the interval of 5 minutes, 50 mL of degraded wastewater was collected and sampled in the 50 mL plastic vials. Meanwhile, the mixed solution sample (industrial wastewater and ZnO-PVP) has been separated using bench top centrifuge (Scanspeed 1580R, Labogene) for 20 minutes at 500 rpm and at room temperature (25°C). After separation, the treated POMSE has been analyzed.

6.5 ANALYSIS OF TREATED WASTEWATER

Color intensity of the treated water samples was determined with UV-Vis Scanning Spectrophotometer (Spectro UV-2650, Labomed, Inc.). Dissolve oxygen (DO) has been measured by using DO meter (HI 9146, HANNA instrument). In order to get an accurate reading, calibration was done before the measuring probe can be used. Then, the probe was rinsed with distilled water and dab with Kimwipe tissue for every samples tested. Next, for turbidity test, the samples were measured by using portable turbidity meter (TN100, EUTECH instrument).

Furthermore, for biological oxygen demand (BOD) test, BOD$_5$ of fresh and treated POMSE were taken. The test was started by preparing the dilution water by using BOD buffer pillows and aerated distilled water. Next, the samples were prepared by gently stirred the samples. Then, a pipette was used to add the sample volumes to 300 mL BOD bottles followed by addition prepared dilution water. In order to prevent air bubbles, the water was poured down at the inner surface of the bottles.

Each of the bottles need to be closed by stopper to prevent trapped air bubbles and need to be inverted several times to mix it. Moreover, the blank was prepared by filled another 300 mL BOD bottle with only the prepared dilution water. Then, the initial DO concentration of each bottles were measured by using DO meter (HI 9146, HANNA instrument). Next, all of the samples were incubated in cooled incubator at 20°C for 5 days. After 5 days, the final DO concentration of all samples tested was measured again so that the BOD$_5$ can be calculated by using formula below:

$$\text{BOD}_5 \text{ (mg/L)} = \frac{(D_1 - D_2)}{P}$$  \hspace{1cm} (3.1)

Where

- $\text{BOD}_5 = \text{BOD value from the 5 day test (mg/L)}$
- $D_1 = \text{DO of the prepared samples immediately after preparation (mg/L)}$
- $D_2 = \text{DO of the prepared sample after incubation of 5 days (mg/L)}$
- $P = \text{Decimal volumetric fraction of sample used}$
6.6 RESULTS AND DISCUSSIONS

In this section, the results of the data analysis are presented. This chapter contains explanation of the data analysis followed by discussion of the research findings.

6.6.1 CHARACTERIZATION OF ZNO-PVP NANOPARTICLES

The purity and crystallinity as well as the properties of chemical bonds and nature of ZnO-PVP nanoparticles have been successfully analyzed by X-Ray Diffractometry (XRD) and Fourier Transform Infrared Spectroscopy (FTIR) respectively. Fig. 3.3 shows the XRD patterns of ZnO-PVP nanoparticles. The peaks are indexed as 31.79° (100), 34.44° (002), 36.27° (101), 47.55° (102), 56.61° (110), 62.87° (103), 66.39° (200), 67.96° (112), 69.10° (201) and 76.97° (202) respectively. All of the indexed peaks in the diffractograms are well matched with that of bulk ZnO (JCPDS Card No. 36–1451) which confirms that the synthesized ZnO-PVP powder is single crystalline and possesses a wurtzite hexagonal structures. No diffraction peaks of other impurities were detected in the XRD pattern, confirming that the high purity of the synthesized ZnO-PVP nanoparticles [8]. Similar, X-ray diffraction pattern were reported by [9]. Moreover, (101) plane has the strongest line indicated that the high crystallinity of the ZnO-PVP nanoparticles.

Fig.3.4 shows FTIR spectra of ZnO-PVP nanoparticles. FTIR analysis was carried out in order to reveals the properties of chemical bonding and nature of ZnO-PVP nanoparticles. As can be seen in the figures above, there are several characteristics absorption band appearing in the range 600-4000 cm⁻¹ due to covalent bonds of PVP [10]. The peaks that appeared at 980 and 610 cm⁻¹ are attributed as the stretching of C-C rings of breathing of pyrrolidone. The absorption bands at 1530 cm⁻¹ due to ZnO stretching and deformation vibration respectively [10]. The results show that C=O bond existed in the range from 2190 until 2300 cm⁻¹ in the sample as stated by [10]. They also revealed that C=O group carboxylic derivatives present due to residue of zinc acetate used in the synthesis of ZnO-PVP nanoparticles. It may happen because of the precursor material and reaction product. The peaks observed from 3000 until 4000 cm⁻¹ represents as the vibration mode O-H group of the moisture which make the bond arises and proved that there is a water absorption on the ZnO-PVP surface [11].
6.6.2 EFFECT OF pH OF SOLUTION

The study of pH is essential to determine the optimum pH condition for the treatment of POMSE. In order to obtain optimum pH value, the photocatalytic degradation of 100% POMSE concentration in presence of 0.08 g/L ZnO-PVP nanoparticles with varying the pH value at pH 4.0, pH 6.5 and pH 9.0 was carried out. The POMSE was treated under UV light irradiation for 15 minutes with 150 rpm of mixing rate.

The adsorption of an anionic dye generally decreases with an increase in pH, and this phenomenon is associated not only with the negative charge on the surface of the adsorbent but also with excess OH\(^-\) ions in the solution that compete for the adsorption sites. Fig. 3.5(i) shows the positive trend of percentage of degradation over time. It revealed that the performance of photocatalytic degradation activity increased as the pH value decreased. Nearly 28% of degradation was achieved at pH value 4 while pH 6.5 and pH 9.0 achieved only 12% and 11% degradation respectively. The acidic condition...
of POMSE incites the degradation rate. Strong acidic condition aggravates POMSE to break dye droplets and destabilization of suspended solid in the suspension. This situation is believed to create more possibility for particles restabilization due to reversal of surface charge, compared to at a higher pH. When the pH was adjusted to a higher value up to pH 9.0, the percentage of degradation was low compared to the acidic condition. This may be attributed to the degree of protonation of the active groups of the photocatalyst surface. This is because the materials responsible for POMSE colour are characterized by the presence of hydroxyl groups, these anionic functions are attracted by protonated groups of the surface. Thus, the protonation of the surface active groups was necessary for the attraction of hydroxyl groups, which led to the color removal [12]. Hence, photocatalytic degradation activity in presence of ZnO-PVP nanoparticles showed a good potential of degradation at lower pH value.

The turbidity of treated POMSE is very relative to the percentage of degradation. It can be seen through Fig. 3.5(i) and Fig. 3.5(ii) which shows that the higher percentage of degradation will also lead to the higher turbidity reduction. The Fig. 3.5(ii) demonstrates that nearly 40% turbidity reduction achieved at pH 4.0 while pH 6.5 and pH 9.0 only achieved 31% and 34% turbidity reduction respectively. The turbidity reduction was higher at pH 4.0 compared to the one at pH 6.5 and pH 9.0. Therefore, photocatalytic degradation process of 100% concentration of POMSE in presence of ZnO-PVP nanoparticles demonstrates the best turbidity reduction in acidic condition, while portrays low efficiencies in neutral and alkaline condition. This is because when the pH value increases, it leads to dissolution of precipitate formed, which indirectly introduces the turbid.

The dissolved oxygen must not exceed the standard discharge limit set by both Department of Environment (DOE) Malaysia and Environment Quality Act (EQA) 1974. Adequate dissolved oxygen is important for good water quality and necessary to all forms of life. Dissolved oxygen levels that drop below 5.0 g/L cause stress to aquatic life. While lower concentrations cause greater stress. Oxygen levels that go below 1-2 mg/L for a few hours may result in large fish kills. Based on the Fig. 3.5(iii), it obviously revealed that at acidic condition (pH 4.0), the treated POMSE contained the highest amount of DO which is 6.62 ppm. The amount of DO started to decrease as the pH value increases at 6.5 and 9.0 where the amount of DO achieved are is 5.14 ppm and 5.63 ppm respectively. However, all the readings of DO obtained still higher than the initial DO of POMSE which is 2.53 ppm indicated that there are increases in amount of DO after the treatment. Besides, it is proved that all treated POMSE was safe to be discharged.

The standard five days BOD₅ value is commonly used to determine the amount of organic pollution in wastewater. Determination of BOD₅ tests are involve measuring the oxygen demand of both the organic matter and organism in the POMSE. It is used to measure the approximate amount of oxygen that will be required by bacteria and other microorganisms while stabilizing the decomposable the organic matter present [13]. The BOD₅ at 20°C is expected to be 50 mg/L and below since discharged limit for industrial effluent for standard B is at 50mg/L. The amount BOD₅ of initial POMSE is 213 mg/L and the amount of BOD₅ for treated POMSE at different pH value of solution are demonstrated in Fig. 3.5(iv). For the use of pH 4.0, the amount of BOD₅ is 149.0 mg/L followed by 118.5 mg/L and 147.0 mg/L for pH 6.5 and 9.0 respectively. Although POMSE has been treated with ZnO-PVP nanoparticles, it is found that there are still high values for BOD. pH 6.5 shows the lowest amount of BOD₅ indicated that the treated
POMSE has less organic matter. That is mean the microorganisms will consume less oxygen to decompose the organic matter in the effluent. Hence, the optimum value of pH 4.0 was used for the photocatalytic degradation of POMSE in presence of ZnO-PVP nanoparticles since the other three graphs (Figure 3.5, Figure 3.6 and Figure 3.7) still show high efficiency of photocatalytic degradation of POMSE.

![Figure 6.5: Effect of pH.](image)

### 6.6.3 EFFECT OF AMOUNT OF LOADING

Effect of different amount of ZnO-PVP nanoparticles on the treatment of POMSE was analyzed. The tests were carried out at optimum pH obtained which is pH 4 with 25% POMSE concentration. Several amount of loading were used to determine the optimum amount of loading ZnO-PVP nanoparticles in the photocatalytic degradation POMSE. The effect of amount of photocatalyst loading was analyzed by varying the dosage of ZnO-PVP nanoparticles (0.08-0.90 g/L).

It was believed that increasing amount of photocatalyst dosage will increased the photocatalytic degradation efficiency. Based on Fig. 3.6(i), the 0.50 g/L amount of ZnO-PVP nanoparticles recorded the lowest percentages of degradation which is 80.37% followed by 0.90 g/L of loading achieve 81.07% of removal. Use of 0.08 g/L of ZnO-PVP nanoparticles was far better than the other high dosage for POMSE photocatalytic degradation since it provides higher percentage of degradation which is up to 81.35%. All of the amounts of loading tested confirmed had improved the degradation of POMSE however, the lowest amount of ZnO-PVP nanoparticles shows the higher percentage of degradation. The results clearly indicate that the efficiency of degradation increases to an
optimum value at ZnO-PVP nanoparticles dosage of 0.08 g/L only. Further increases in ZnO-PVP nanoparticles dosage have no significant effect on POMSE. This could be explained by the fact that equilibrium has been reached between the photocatalyst and POMSE, thereby, preventing further degradation [12]. Therefore, the results show that ZnO-PVP nanoparticles is a good photocatalyst for degradation of POMSE even at lower dosage.

According to [14], that the percentage of turbidity reduction increases with an increase in the amount of photocatalyst up to a level above saturation phase corresponding to the optimum light absorption. The increase of amount of loading will causes cloudiness of the solution in contact with the photocatalyst and this further leads to decrease in the surface area exposed to irradiation. These made the suspended particles of the photocatalyst block the UV-light passage and increase the light scattering and thus decrease the photocatalytic effectiveness of the process. Based on Fig. 3.6(ii), it shows that for the use of 0.08 g/L of ZnO-PVP nanoparticles achieved turbidity reduction up to 83.14%. However, there is slightly turbidity increment of treated POMSE as the dosage increased. Use of 0.50 g/L ZnO-PVP nanoparticles achieved relatively low turbidity reduction 77.98% while for the use of 0.90 g/L ZnO-PVP nanoparticles being the most turbid by showing the lowest turbidity reduction percentage among all which is 72.29%. As expected, the treatment of POMSE by using the lowest of amount ZnO-PVP nanoparticles has the highest percentage of turbidity reduction throughout the series of dosage tested. Any further increase above 0.08 g/L of the photocatalyst has no effect on the photodegradation efficiency.

Fig. 3.6 (iii) demonstrated the amount of dissolved oxygen of treated POMSE and the results obviously stated that use of 0.08 g/L of ZnO-PVP nanoparticles contained 6.64 ppm of DO in treated POMSE. For use of 0.50 g/L of photocatalyst contained highest amount of DO which is 7.47 ppm followed by the use of 0.90 g/L ZnO-PVP nanoparticles which contained 7.19 ppm. It can be seen that there are unstable reading of DO as the amount of loading being increases. The unstable reading of DO occurred due to the presence of oxygen in photocatalytic degradation which acts as electron acceptor that used to trap the photo induced \( e^- \). In addition, they also stated that the unstable DO concentration was related to the generated oxygen was involved in the mineralization of POMSE [15].

POMSE is an important source of inland water pollution when released into local rivers or lakes without treatment because it is a highly polluted wastewater that pollutes the environment if discharged directly due to its high BOD concentration. Treatment of POMSE is necessary to further reduce BOD concentration in order to produce effluent that complies to discharge standards [16]. The amount of BOD\(_5\) for treated POMSE at different amount of ZnO-PVP nanoparticles are showed on Fig. 3.6(iv). For the use of 0.08 g/L ZnO-PVP nanoparticles, the amount of BOD\(_5\) is relatively low which is 101.0 mg/L followed by 126.0 mg/L and 138.0 mg/L for 0.50 g/L and 0.90 g/L photocatalyst respectively. 0.08 g/L ZnO-PVP nanoparticles has been confirmed that have the lowest amount of BOD\(_5\). Hence, the optimum amount of 0.08 g/L ZnO-PVP nanoparticles was used for the photocatalytic degradation of POMSE.
6.6.4 EFFECT OF CONCENTRATION

It is important both from mechanistic and an application point of view to study the dependence of photocatalytic reaction on the substrate concentration. Hence, the effect of substrate concentration on the degradation of POMSE was studied by varying the concentrations of POMSE from 25% until 100% at constant pH 4 and 0.08 g/L ZnO-PVP nanoparticles.

The percentage of degradation depends on the initial POMSE concentration. The dependence of photocatalytic degradation activity of POMSE on the concentration may be due to the following reasons. When the POMSE concentration increases the amount of dye adsorbed on the photocatalytic surface increases. This affects the photocatalytic activity of the photocatalyst. The increase in POMSE concentration also decreases the path length of photon entering into the dye solution. At high POMSE concentration the dye molecules may absorb a significant amount of light rather than the photocatalyst and this may also reduce the photocatalytic efficiency [17]. As it can be seen from the Fig. 3.75(i), the slopes show that the percentage of degradation is decreases as the POMSE concentration increases and the percentage of degradation at all particular POMSE concentration increases at a faster rate in the initial 2 minutes and then continued constant afterwards. 81.35% degradation was achieved when the POMSE concentration
is at 25%. However, when the concentration increases up to 100%, the efficiency of colour removal decreases. Only 58.55% and 27.21% degradation were achieved for the use 50% and 100% concentration of POMSE respectively. As expected from the previous research, the efficiency of degradation increases rapidly at low concentration of POMSE and then changes slowly as the concentration increases.

The higher the degradation rate leads to the less turbid of POMSE. Based on the Fig. 3.7(ii), maximum percentage of turbidity reduction which is 83.14% was obtained at 25% concentration of POMSE followed by 55.23% removal at 50% concentration. At POMSE concentration of 100%, there is very little turbidity reduction which is at 39.27%. Besides, it was observed that treated 25% concentration of POMSE was less cloudy in comparison the other concentration. This is due to the percentage of degradation of POMSE is higher.

The DO in rivers is crucial for the organisms and creatures living in it. As the amount of dissolved oxygen drops below normal levels in water bodies, the water quality is harmed and creatures begin to die off. Indeed, a water body can die due to a process called eutrophication. Therefore, the DO of treated POMSE must be followed the criterion standard of EQA and DOE so it can be discharge to the river. Fig. 3.7 (iii) shows the amount of DO for three different concentration of POMSE. It was observed that 25% concentration of POMSE achieved 6.64 ppm of DO while both for 50% and 100% concentration contained 6.62 ppm of DO. Based on the results, the amount of DO of treated POMSE at all particular concentration obtained was safe to be discharged at rivers or lakes.

BOD₅ is an important parameter in POMSE quality measurement and indicates the photocatalysis processes surpass in the POMSE degradation. The amount of BOD₅ for treated POMSE at different concentration were showed on Fig. 3.7(iv). For the use of 25% concentration, the amount of BOD₅ is relatively low which is 101.0 mg/L followed by 122.0 mg/L and 149.0 mg/L for 50% and 100% concentration of POMSE. The use 25% concentration of POMSE has been confirmed that have the lowest amount of BOD₅ indicated that low biodegradable organic compounds in treated wastewater. Besides, it shows that the high ability of naturally occurring microorganisms to digest organic matter. Hence, the optimum concentration of 25% of POMSE was used for the photocatalytic degradation of POMSE in presence of ZnO-PVP nanoparticles.
6.7 CONCLUSION

The synthesized ZnO-PVP powder is a pure single crystalline which possess a wurtzite hexagonal structures and have several characteristics absorption band due to covalent bonds of PVP. The optimum conditions for photocatalytic degradation of POMSE are successfully identified at pH 4 with 25% concentration of POMSE in presence of 0.08 g/L of ZnO-PVP nanoparticles. The analysis of treated POMSE shows that the treatment under optimum condition has the best results where the percentage of degradation achieved is up to 81.5% with 83.14% of turbidity reduction and contained 6.64 ppm amount of dissolved oxygen as well 101.0 mg/L of BOD₅.

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REFERENCES


