Improving the quality of palm oil liquid waste using nanocomposite TiO$_2$/EPB activated carbon through adsorption-photodegradation

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Abstract. Research has been carried out on the use of nanocomposite of TiO$_2$/activated carbon in reducing the quality parameters of palm oil liquid waste through the adsorption-photodegradation mechanism with DO (dissolved oxygen) parameters. Characterization of samples catalyst nanocomposite of TiO$_2$/activated carbon was used using Scanning Electron Microscopy (SEM-EDX) and DO parameters with variations in the mass percentage ratio of TiO$_2$/activated carbon are namely (0.4:0.3), (0.6:0.4), (0.5:0.5), (0.4:0.6), and (0.7:0.3). SEM-EDX shows that TiO$_2$ particles stick and spread unevenly on the surface of the activated carbon, and the ratio of the atomic mass of titanium to sample abundance is 0.25. Based on the analysis of DO of palm oil liquid waste using catalyst nanocomposite of TiO$_2$/activated carbon, it is known that the DO value of palm oil liquid waste increases with the increase in contact time of the TiO$_2$/activated carbon sample with sunlight. This indicates that TiO$_2$/activated carbon can degrade the presence of hazardous chemicals in palm oil liquid waste through the adsorption-photodegradation mechanism.

Keywords: Nanocomposite, activated carbon, adsorption, photodegradation.

Introduction

Palm oil is the main ingredient for producing palm oil. The very promising prospect of palm oil commodity has spurred the Indonesian government to develop oil palm plantation areas. Processing activities in the palm oil industry produce three types of waste. First is solid waste in the form of shells, midribs and empty palm oil bunches (EPB), then liquid waste is generated from the palm oil refining process. Finally, the waste gas produced from the combustion process of this liquid waste is generally toxic and can cause disease in humans and cause damage to other environmental components (Novia Yanti and Hutamasuh, 2020). The negative impact of the waste produced requires Palm Oil Mills (POM) to carry out waste disposal properly and correctly. EPB is biomass rich in carbon elements, thus making EPB has the potential as activated carbon. Activated carbon has many uses as an adsorbent because it has a high absorption capacity due to pores in the activated carbon material (Fatmawati et al., 2021; Ningsih et al., 2017).

Activated carbon can be specified as a carbon material with an amorphous and broad structure large internal surface with high porosity (Rosmalinda et al.) (Huda et al., 2020). The Carbon form of activated carbon is microcrystalline and non-graphite. The non-graphite record consists of a small amount of hydrogen or large amounts of oxygen in the structure. (Yang et al., 2019). In recent years, active carbon has been used because it has increased surface reactivity, excellent thermal stability, and electrical conductivity (Shi et al., 2013; Rahmawati et al., 2019). This structure has an essential role in determining the performance of activated carbon as adsorbent.

Various research efforts have been carried out to reduce the liquid waste produced by the palm oil industry. One of them is using a photocatalyst process. The photocatalyst process is a chemical reaction process that involves a reaction accelerator (catalyst) and the process is assisted by sunlight or UV lamps (Tussa’adah, 2015). The photocatalysis process with TiO$_2$ as a photocatalyst has provided solutions to various problems in the environment, including the purification of either water or air, as a degrading agent for dyes and chemical compounds that are toxic. Such as photocatalyst research conducted by (Arutanti and Abdullah, 2009) utilizing TiO$_2$ compounds is also proven to be able to process toxic organic substances into other non-toxic substances in polluted water.

In addition to TiO$_2$ compounds, it can also use EPB which is a solid waste, which is then activated into active carbon and applied as an adsorbent. TiO$_2$ compounds that are positioned on active carbon become a nanocomposite material that has a variety of functions, including the nature of the porous active carbon that can function as an adsorbent and as a photodegrade to obtain a more efficient and effective material (Septiani et al., 2015; Agustin et al., 2013).
Based on the description that has been explained, this study aims to examine the ability of Nanocomposite TiO2/EPB active carbon to degrade palm oil effluent through the photodegradation-adsorption method. This test using the DO (Dissolved Oxygen) parameter.

**Method and Materials**

The sample in research was collected in PPKS Aramiah, Aceh Province. The chemicals used in this research were titanium isopropoxide, triethanolamine, sodium hydroxide, and distilled water.

**1. Sample Preparation**

The sample in this study consisted of TiO$_2$ and activated carbon. TiO$_2$ powder was obtained from the synthesis by the sol gel method. The first step is to produce a solution of 0.5 M Ti$^{4+}$ through a mixture of titanium isopropoxide and triethanolamine in a ratio of 1:2, and then the mixture add distilled water. Then NaOH was added to obtain a pH of 9.6. The resulting solution was heated in an oven at a temperature of 100°C for 24 hours. Then the oven temperature was increased to 140°C and held for 72 hours and cooled to room temperature (Chen and Mao, 2007).

Activated carbon was obtained from EPB samples taken from PPKS Aramiah. EPB was cut into small pieces, then dried in the oven at a temperature of 110°C for 24 hours. Then activated using a furnace at a temperature of 70°C for 1 hour. Carbon that has been formed is ground using a grinder until smooth and then sieved with a sieve size of 60 mesh (Rahmawati et al., 2017).

**2. Synthesis of Nanocomposite TiO$_2$/EPB Activated Carbon**

Synthesis of nanocomposites begins by making a solution of 2% TiO$_2$ suspension mixed in acrylic resin until there is no mixed precipitate between the two. Furthermore, a mixture of TiO$_2$/resin (emulsion coating TiO$_2$) can be deposited on a substrate in the form of EPB activated carbon. The coating results then washed with distilled water until clean through a filtering process. Then the precipitate was dried at a temperature of 100°C for 1 hour [8]. Furthermore, the coating results were characterized using Scanning Electron Microscopy (SEM).

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Nanoparticles</th>
<th>Activated Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>M2</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>M3</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>M4</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>M5</td>
<td>0.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**3. Sample Characterization**

Testing the photodegradation activity of TiO$_2$ nanocomposite/EPB activated carbon was carried out by measuring the value of DO (Dissolved Oxygen) content. 100 mL of palm oil liquid waste deposited with TiO$_2$ nanocomposite/activated carbon which was irradiated with the sun with a long exposure of 1, 3, and 5 hours. The palm oil effluent samples were then analyzed DO parameters.

**Results and Discussion**

1. **Scanning electron microscope (SEM) Analysis**

The results Scanning electron microscope (SEM) analysis of all samples (activated carbon, TiO$_2$, and nanocomposite of TiO$_2$/activated carbon with a magnification of 50000 times represented in Figure 1. The Figure 1 shows that activated carbon has pores and is in the form of bars. Overall, the surface morphology of the TiO$_2$ composite material /EPB activated carbon with various variations shows that the TiO$_2$ particles are spread unevenly and stick to the surface of the activated carbon.

![SEM analysis results](image)

**Table 1. Mass percentage ratio of TiO$_2$ and activated carbon of oil palm empty fruit bunches.**

<table>
<thead>
<tr>
<th>Material Name</th>
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<th>Activated Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>M2</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>M3</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>M4</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>M5</td>
<td>0.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Figure 1. SEM analysis results (i) Activated carbon, (ii) TiO$_2$, (iii) M1, (iv) M2, (v.) M3, (vi) M4, (vii) M5 at a magnification of 5000 times.
The results of the overall SEM-EDX analysis, the ratio of carbon atoms to titanium atoms is smaller than 1 (NC/NTi < 1). It can be explained that NTi/N Total, namely the ratio of titanium atoms to the number of atoms in the sample is also smaller than 0.5 (NTi/N Total < 0.5). This can be seen from the very small percentage of titanium atoms (< 0.1) in each sample. As for the atomic mass percentage analysis, it can be seen that the ratio of the number of atomic masses of carbon to the number of atomic masses of titanium in each Sample 1 is 1 (MC/MTi ≥ 1). The ratio of the atomic mass of titanium to the mass of the sample can be shown in Table 2, which shows a pattern resulting from the ratio of the atomic mass of titanium to the mass of the sample, which is a ratio of 0.25. This pattern is also obtained from the ratio of the number of atomic masses of carbon to the atomic mass of titanium. This is because the atomic mass of titanium is very large compared to carbon atom (the atomic mass of titanium is 4 times compared to carbon atom).

Figure 2. Results of Empty Waste DO Analysis Against Time (a) Activated carbon (b) TiO₂ (c) M1 (d) M2 (e) M3 (d) M4 (g) M5

Ket;

- DO analysis of Sample
- DO analysis of empty waste
2. DO (Dissolved Oxygen) Analysis

DO or Dissolved Oxygen content is the amount of oxygen content in water. DO is one of the parameters used to measure the quality of palm oil effluent. The DO value greatly determines the level of pollution that occurs in the aquatic environment. The higher the DO value, the lower the level of pollution in the waters and vice versa. If the DO value increases, the BOD value in the waters actually decreases. The results of the DO analysis of empty waste for activated carbon, TiO$_2$, and samples of TiO$_2$/TTKS activated carbon with various weight variations (Samples 1-5) are shown in Figure 2.

In Figure 2, it can be seen that all samples of TiO$_2$/Activated carbon of EPB (Samples M1-M5) showed an increase in DO value in the sample of TiO$_2$/Activated carbon of EPB when compared to empty waste. In addition, the DO value of palm oil effluent increased with increasing contact time of TiO$_2$/EPB activated carbon samples with sunlight. This indicates that the photocatalyst effect of the TiO$_2$/EPB activated carbon sample is able to degrade the presence of hazardous chemicals in the palm oil liquid waste, thereby reducing the pollutants contained in the palm oil liquid waste.

Table 3. The difference in the final DO value (after 5 hours)

<table>
<thead>
<tr>
<th>Name</th>
<th>Final DO value (mg/L)</th>
<th>The difference between the final DO relative to the final DO of empty waste (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated Carbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>6.905</td>
<td>0.205</td>
</tr>
<tr>
<td>M1</td>
<td>4.55</td>
<td>2.56</td>
</tr>
<tr>
<td>M2</td>
<td>5.055</td>
<td>2.055</td>
</tr>
<tr>
<td>M3</td>
<td>3.755</td>
<td>3.355</td>
</tr>
<tr>
<td>M4</td>
<td>4.095</td>
<td>3.015</td>
</tr>
<tr>
<td>M5</td>
<td>3.17</td>
<td>3.94</td>
</tr>
</tbody>
</table>

Based on Table 2. above, it can be concluded that the DO values of the samples of TiO$_2$/EPB activated carbon, TiO$_2$, and activated carbon respectively are as follows TiO$_2$ < M2 < M1 < M4 < M3 < M5 < Activated carbon. From each sample tested, it was found that Sample 2 contained high levels of DO. This is because the ratio of carbon atoms to titanium atoms is small when compared to other samples. For a ratio close to 1, it means that the number of titanium atoms is the same as that of carbon atoms. Consequently, DO levels will increase. Based on the DO data, it can be concluded that the TiO$_2$/EPB activated carbon sample with high titanium atom content increases the efficiency of waste decomposition and results in high DO levels.

Conclusion

From the results of the study, it was found that the DO value of palm oil effluent increased along with the increase in contact time of TiO$_2$/EPB activated carbon samples with sunlight. This identified that the photocatalyst effect of the TiO$_2$/EPB activated carbon sample was able to reduce the presence of hazardous chemical content in palm oil liquid waste through an adsorption-degradation mechanism so as to reduce the pollutants contained in palm oil liquid waste.

References


