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Palm Kernel Shell as Potential Adsorbent for Treatment and Decolorization of Palm Oil Mill Effluent (POME)

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Abstract

The issue of POME is an important concern in Malaysia as a result of the extensive production of palm oil. This is due to the fact that POME is a liquid with a high concentration of organic matter, which poses a significant threat to the environment. Unresolved discharge of Palm Oil Mill Effluent (POME) will result in significant issues, either directly or indirectly. Therefore, activated carbon derived from palm kernel shells (PKS) was utilized in this work for the treatment of palm oil mill effluent (POME). The adoption of this approach was undertaken in order to accomplish three specific objectives of this study. To begin with, parameters were analyzed for BOD, COD, pH, turbidity, and decolorization conditions for POME. Finally, the re-usability of PKS as a potential adsorbent for treating and decolorizing POME was determined. The investigation employed an adsorption procedure in which the PKS was thoroughly cleaned and physically activated in a 500°C oven before being ground into a powder with a particle size of 150 microns. The adsorption process started by mixing the powdered PKS with a dosage range of 10g to 30g into the POME with different concentrations, which are 100%, 90%, and 80%, respectively. The adsorption process was carried out for a duration of 60 minutes, 120 minutes, and 180 minutes using an orbital shaker with a 110 rpm agitation rate. The maximum percentage elimination of BOD, COD, pH value, turbidity, and color is 73.34%, 69.83%, 41.5%, 10.5%, and 43.7%, respectively. PKS have a significant capacity to eliminate organic pollutants and color in POME. The PKS, which is the raw material found in the palm oil mill, can be transformed into activated carbon and utilized as a sustainable method for treating POME.

1. Introduction

Palm oil processing generates enormous amount of wastewater, the palm oil mill effluent (POME), containing various recalcitrant pollutants. POME exists as brownish liquid and viscous, hence, the effluent would seriously harm the ecosystem and pollute it if it were released into the sources directly. POME, short for Palm Oil Mill Effluent, refers to the wastewater that is generated during oil palm processing and contains various types of suspended substances. The biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels in POME are 100 times higher than those in municipal sewage. The effluent also contains a greater concentration of organic nitrogen, phosphorus, and several supplementary chemicals. If these substances are not appropriately managed, they can result in significant harm to the environment and endanger aquatic organisms. Additionally, the high amounts of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in palm oil mill effluent (POME) can lower the amount of oxygen in water, which can throw ecological balance off even more [1].

Malaysia has been utilizing a range of POME treatment methods since the early 2000s. The prevailing treatment method being employed is the implementation of ponding systems. Mohammad et al. (2021) reported that this technique treated up to 85% of POME [2]. The reasons for this are cost-effectiveness, minimal maintenance costs, simple design, and energy efficiency. Ponding systems collect Palm Oil Mill Effluent (POME) in large, open ponds. The organic matter undergoes anaerobic digestion to decompose and reduce its pollution levels [3]. Nevertheless, there are several disadvantages associated with the utilization of a ponding system for POME treatment. Although widely favored, ponding systems have been linked to several environmental issues, including the emission of greenhouse gases and the possibility of fertilizer leaking into nearby water bodies. Ponding systems also need a very lengthy retention time and a very vast area.

Due to these issues, POME discharges frequently fell short of the standards that the Department of Environment (DOE) has set. There are specific regulations that have been set up for POME discharge, named the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977, under the Environmental Quality (Scheduled Wastes) Regulations 2005. This regulation states that any discharge of POME must comply with the limitation values for bio-chemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), oil and grease (O&G), and others as specified in the regulations. Failure to comply with these limitations may result in penalties or legal consequences. These regulations aim to control and minimize the environmental impact of POME discharge by ensuring that it meets certain standards.

Malaysia's extensive palm oil output results in a substantial quantity of palm kernel shell (PKS) being produced. In 2020, Malaysia's global exports of PKS amounted to over 1 million metric tons. Japan dominates the market, accounting for 99.6% of the share, which is equivalent to 981,624 MT. In 2020, the export value of PKS amounted to RM365.36 million, representing approximately 0.25% of the overall export value of oil palm goods [4]. Therefore, due to its reusability and versatility, PKS can be utilized as a promising adsorbent for the treatment of POME. POME, short for palm oil mill effluent, is a residual substance generated during the manufacture of palm oil and is recognized for its substantial concentration of pollutants. By employing PKS as an adsorbent for POME treatment, it not only offers a sustainable waste management solution but also contributes to mitigating the environmental consequences of the palm oil sector. Furthermore, employing PKS as an adsorbent has the potential to result in cost savings for palm oil mills by obviating the necessity for costly chemical treatments.

2. Materials and Methods

2.1 Materials

The collected palm kernel shells (PKS) were cleaned several times. The PKS was then air- and sun-dried. The PKS is sorted out before blending, considering it is mixed with other foreign matter during the collection process in the factory, such as bricks. After that, the PKS was activated via physical activation where PKS being heated in the oven at 500°C for about an hour before being ground into smaller particles. The PKS were blended in a heavy-duty blender and sieved through a 150-micron sieve. Figure 2.1 shows the PKS after being sieved.

Fig. 2.1 *PKS after sieving using 150 micron siever*

2.2 Methods

A 500 mL beaker containing blended PKS was combined with the POME sample. PKS dosage ranges of 10g to 30g were combined with 400mL of POME, which was in different concentrations that were set to 100%, 90%, and 80%. For each of the three distinct mixed samples, the contact time for the adsorption process was set to three hours, two hours, and one hour. To enhance and guarantee the consistency of the sample mixing, the beaker with the combined sample was then set on the orbital shaker with a constant speed of 110 rpm.

Table 2.1 *Types of parameters and the values for each parameters*

Type of parameters	Value of each Parameters
Contact Time (minutes)	60, 120, 180
PKS Dosage (g)	10, 20, 30
POME Concentration (%)	100, 90, 80

2.3 Removal Efficiency

By using the formula in Equation 1, percentage removal for BOD, COD, pH, turbidity, and color was computed in this research to determine the re-usability and effectiveness of PKS in treating and decolorize POME.

$$Removal\ rate, \% = \frac{(C_i - C_f)}{C_i} \times 100 \quad (1)$$

C_i = initial concentration, mg/L
C_f = final concentration, mg/L

3. Results and Discussion

3.1 Effect of Contact Time (minutes)

The graph illustrates a clear correlation between increased contact time and a substantial decrease in BOD, COD, turbidity, pH, and color in POME. BOD had the highest percentage removal (73.34%), followed by COD, color, turbidity, and pH at 69.8%, 43.7%, 41.5%, and 10.5%, respectively. This study found that the optimal contact time was 180 minutes. These findings suggest that a contact time of 180 minutes is optimal for eliminating color-causing substances from POME. This indicates that the higher the contact time, the greater the efficiency of adsorption between PKS and pollutants in the POME. As for the percentage removal, the PKS work perfectly fine in reducing the pollutant value.

In the research that has been carried out, Nayl et al. (2017) found that the absorption of COD and BOD by activated carbon occurred rapidly within the initial 150 minutes [5]. After a duration of 150 minutes, there was no significant change observed over time in the adsorption of COD and BOD from treated sewage by activated carbon derived from POME. This shows that the effect of contact time on the adsorption process is significantly crucial to ensuring that the porous area of PKS can adsorb pollutant content as much as possible. The research findings suggest that the contact time in the adsorption process plays a crucial role in ensuring that the porous area of PKS can effectively adsorb pollutant content. In addition, it is worth noting that as the contact time increases, the likelihood of the adsorption process also increases. However, once a state of equilibrium is reached, the adsorbent tends to release the adsorbate due to the saturation of its pores. Consequently, the percentage of adsorbed substances decreases, indicating that the activated carbon has reached its optimal conditions [6].

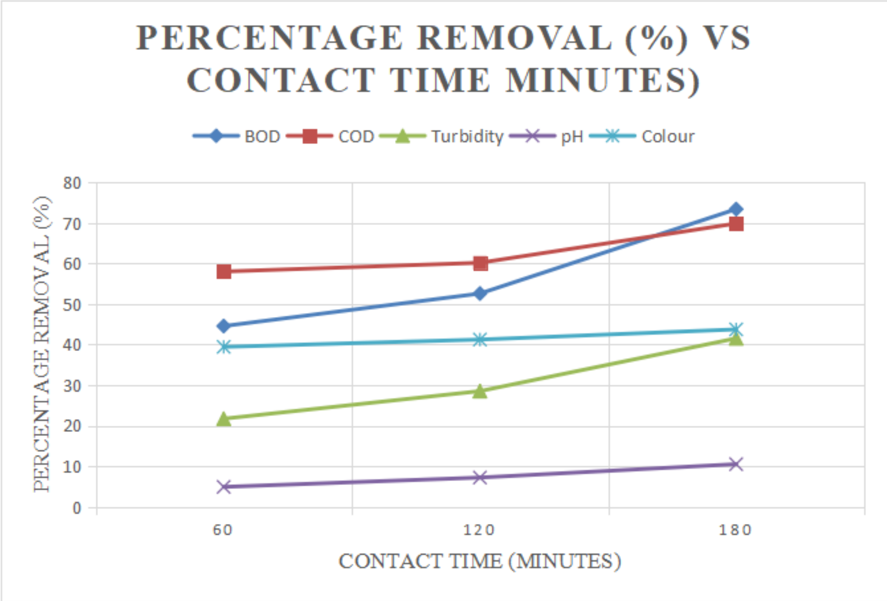

Fig. 3.1 *Percentage removal versus contact time*

3.2 Effect of PKS Dosage (g)

According to the graph, there is an inverse relationship between the dosage and the percentage removal, meaning that as the dosage decreases, the percentage removal increases. BOD had the highest removal percentage (73.34%), followed by COD, color, turbidity, and pH at 69.8%, 43.7%, 41.5%, and 10.5%, respectively. The PKS dosage varied from 10 g to 30 g. The data obtained showed that 10 g of PKS was the optimal dosage for this study. According to Yan Ying et al. (2021), percentage removal increases with the adsorbent dosage [7]. However, Singh and Choden (2014) suggest that, while increasing the amount of adsorbent, a significant portion of the potential adsorption sites may remain unoccupied [8]. The surplus dosage of PKS will remain as residue in the POME rather than being used for treatment. This suggests that there is a threshold dosage of PKS that maximizes the percentage removal. Beyond this optimal dosage, further increases in PKS dosage do not lead to additional improvements in removal efficiency. Adsorbent dosage plays a crucial role in achieving maximum removal efficiency. Yet the optimal value must be determined through experimentation and optimization techniques. This is because there is a point of diminishing returns where if there is an unnecessary amount of PKS, it will disrupt other parameter values. It is important to find the right balance. These data indicate that it is important to carefully determine the optimal dosage of PKS in order to avoid unnecessary waste and the accumulation of excess residue in the POME.

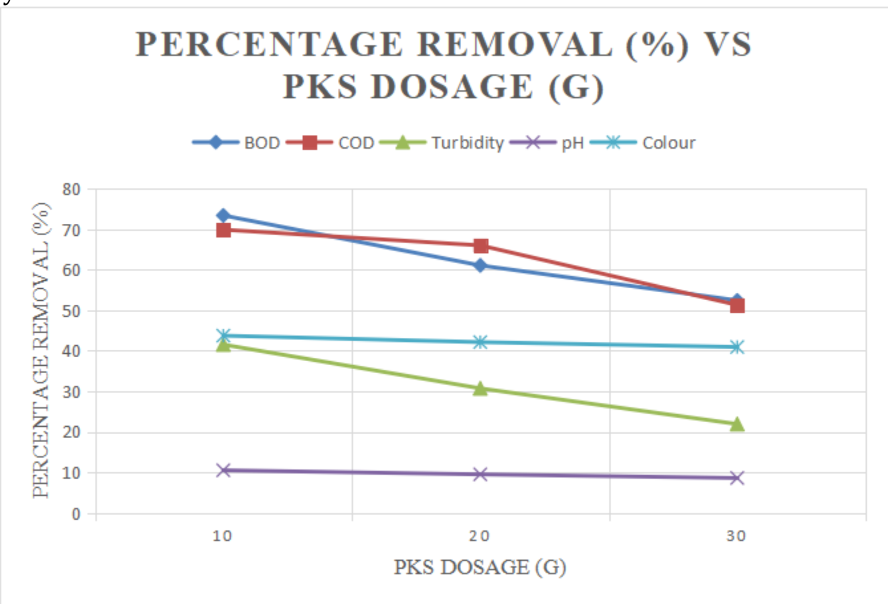

Fig. 3.2 *Percentage removal versus PKS dosage*

3.3 Effect of POME Concentration (%)

The graph illustrates the relationship between the percentage removal of pollutants and the concentration of POME. It indicates that as the POME concentration increases, the percentage removal of pollutants decreases. The diluting of POME concentration will help lower the pollutant content in it. According to Che Sayuti and Mohd Azoddein (2015), POME needs to be diluted to reduce the pollutant concentration and enhance the efficiency of pollutant removal [8]. The researchers also suggest that the optimal dosage of PKS should be determined based on the desired level of pollutant removal and the initial concentration of POME. By finding the right balance between dilution and PKS dosage, it is possible to achieve effective pollutant removal without generating excessive waste or residue. In the study, Mohammad et al. (2021) found that a lower concentration of POME resulted in a higher efficiency of pollutant removal [9]. This suggests that diluting POME before treatment can significantly improve the effectiveness of pollutant removal processes. Therefore, it is crucial to carefully consider the initial concentration of POME and determine the optimal dosage of PKS to achieve the desired level of pollutant removal while minimizing waste generation.

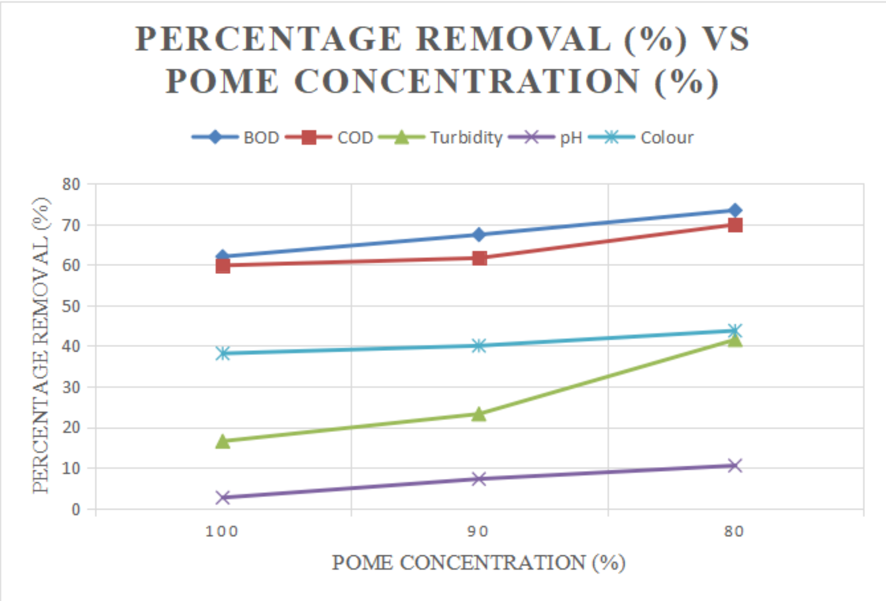

Fig. 3.3 *Percentage removal versus POME concentration*

4. Conclusion

The findings of this study suggest that the use of PKS in POME treatment can effectively reduce levels of BOD, COD, pH, turbidity, and decolorization in the treated palm oil mill effluent. This indicates that incorporating PKS into the adsorption process has the potential to greatly improve the overall effectiveness of POME treatment. The maximum percentage elimination of BOD, COD, pH value, turbidity, and color is 73.34%, 69.83%, 41.5%, 10.5%, and 43.7%, respectively. PKS have a significant capacity to eliminate organic pollutants and color in POME. The PKS, which is the raw material found in the palm oil mill, can be transformed into activated carbon and utilized as a sustainable method for treating POME.

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