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Potential of Banana Stem as Bio-adsorbent for Palm Oil Mill Effluent (POME) Treatment: A Systematic Literature Review

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Abstract: First Banana stem is an agricultural waste where abundance of unusable banana stem can be considered as increase in amount of waste. This research was aimed to investigate the potential of banana stem as bio-adsorbent in palm oil mill effluent (POME) treatment, in order address the increase amount of banana stem as agricultural waste. In this research, adsorbing capabilities of banana stem as bio-adsorbent and various data supporting the potential of banana stem were investigated based on previous literature and findings through systematic literature review (SLR) method. The banana stem adsorbing capabilities studied in this research were focussed on the removal of heavy metal, reduction of chemical oxygen demand, removal of suspended solid and turbidity. The data obtained shows that banana stem have the ability to adsorb heavy metal such as copper ion, zinc ion and iron ions which exist in palm oil mill effluent (POME). The data also shows that banana stem bio-adsorbent are capable of reducing chemical oxygen demand (COD) value of various wastewater up to more than 50.00 % and are capable of reducing the amount of suspended solids and turbidity. Based on the results we can assumed that banana stem bio-adsorbent can be an alternative method in palm oil mill effluent (POME) treatment. However, further laboratory work should be done in the future to prove this claims.

Keywords: Banana Stem, Bio-Adsorbent, Palm Oil Mill Effluent Treatment

1. Introduction

In agricultural industry, banana is also one of the popular fruit crop in Malaysia. It is stated in the Malaysian government statistics report that there are approximately are approximately 29 270 hectares of banana being planted in 2012 that can produced yield of banana for around 29 4530 metric tonnes [1]. Due to this, there is abundance of banana stem each time the banana fruit was harvested in a certain banana plantation because the stem was cut right after the fruit was harvested.

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In order to reduce the abundance of banana stem, this study aims to investigate the potential of banana stem to be used as bio-adsorbent in palm oil mill effluent (POME) treatment. This will incorporates both waste from the palm oil industry and the banana plantation industry that were growing in Malaysia since the project uses the unusable banana stem from banana plantation industry to treat waste from the palm oil industry. By using banana stem that is organic for the palm oil mill effluent (POME) treatment can result in better environmental quality. This study will investigate the potential of banana stem to reduce the chemical oxygen demand (COD) value and other parameters of the palm oil mill effluent (POME) that can contributes towards environmental issue because it can caused depletion in the oxygen content for natural water environment when it was discharged [2].

Palm oil mill effluent (POME) was said to be as the most difficult and expensive waste to manage by the waste operators [3]. Current conventional technique used as the solution for POME wastewater treatment is open pond system, membrane filtration technology and a technique that utilizes coagulation and flocculation [4]. Through this study, an alternative way of treating palm oil mill effluent (POME) are going to be investigated. Study regarding the capabilities of banana stem as bio-adsorbent will be study according to few parameters which are removal of heavy metal ions, removal of suspended solids and turbidity, and reduction of chemical oxygen demand (COD) value of wastewater because all of those parameters are important in palm oil mill effluent (POME) treatment [5].

1.1 Objectives

This study focus on towards the potential of banana stem as bio-adsorbent in palm oil mill effluent (POME) treatment. The effect of wastewater treatment with banana stem on the amount of heavy metal ions, turbidity, suspended solid and chemical oxygen demand (COD) will also be investigated in this study. The effect of working parameters such as pH value, agitation speed and contact time on the adsorbing capabilities of banana stem bio-adsorbent will also be studied.

1.2 Scope of Study

This study focus on Previous findings on the effect of water treatment focusing on the removal of suspended solid, removal of turbidity and chemical oxygen demand (COD) with the usage of banana stem bio-adsorbent. Data from previous study were extracted and discussed to see the potential of banana stem as bio-adsorbent in palm oil mill effluent (POME) treatment. Supporting information such as literature containing data related to the content of banana stem and functional groups existing in banana stem that can prove and support the claims of the potential of banana stem as bio-adsorbent for palm oil mill effluent (POME) treatment were collected.

2. Methodology

This research used one of systematic literature review (SLR) method which is Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). This method of systematic literature review (SLR) consists of few main steps which are development of research objectives, database selection, keywords selection, development of inclusion and exclusion criteria, manuscript or literature collection, screening, data analysis and reporting. The overall research methodology flowchart was shown in Figure 1.

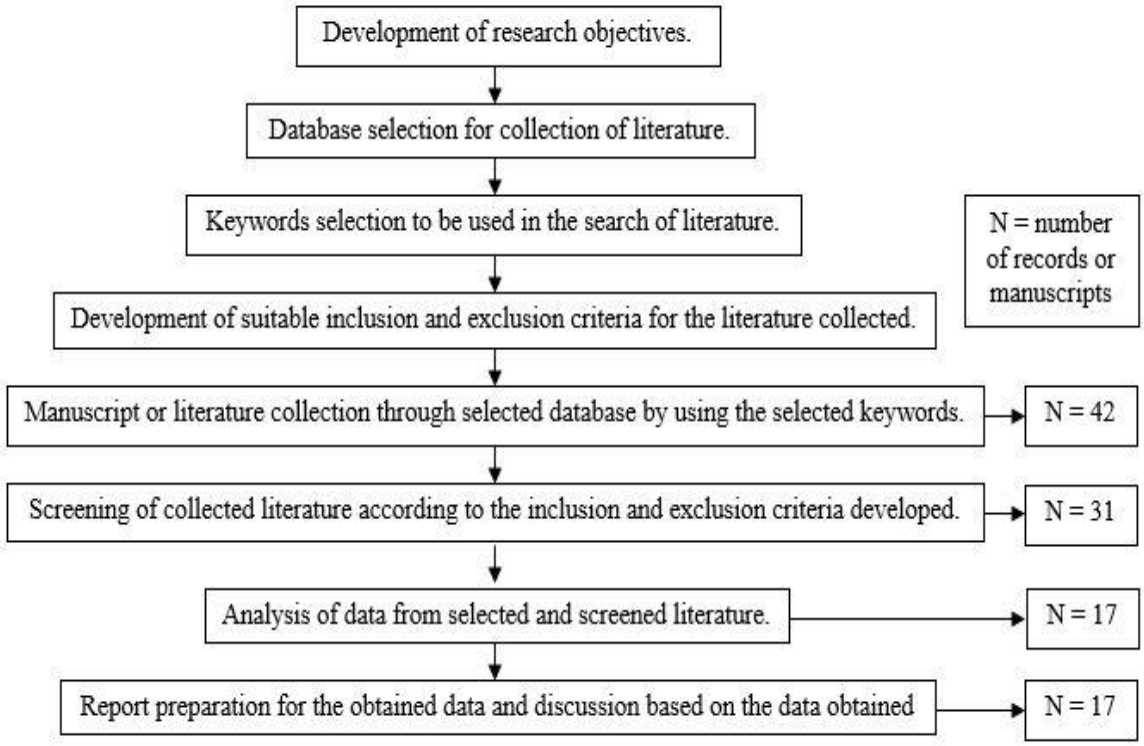

Figure 1: Methodology flowchart

2.1 Development of Research Objectives

Objectives is important for every research because research were made based on the pre-determined objectives. The extracted and analysed data from this study were made based on the objectives. The developed objectives for this study were to study the potential of banana stem as bio-adsorbent in palm oil mill effluent (POME) treatment, to analyse the content of banana stem that can contributes towards the potential of banana stem to be used as bio-adsorbent in palm oil mill effluent (POME) treatment and to investigate the effect of wastewater treatment with banana stem on the amount of heavy metal ions, turbidity, suspended solid and chemical oxygen demand (COD).

2.2 Database Selection

Various database for the collection of literature were used in this study. Keywords for this study were searched on the selected database. The database were selected based on their suitability and credibility. The selected database for this study were “ScienceDirect”, “Wiley Online Library”, “Google Scholar”, “SpringerOpen”, “Scopus” and “Microsoft Academic".

2.3 Keywords Selection

Basic keywords is important for literature identification. Suitable and appropriate keywords can also be used as initial screening. Basic keywords relevant to the study were obtained through the research questions or objectives [6]. Keywords used in this study are “Banana Stem content”, “Wastewater treatment with Banana Stem”, “Banana stem bio-adsorbent”, “Functional group in Banana Stem”, “Palm oil mill effluent (POME)” and “Adsorption”.

2.4 Development of Inclusion and Exclusion Criteria

Various literature were obtained through the database so inclusion and exclusion criteria were develop to be used as a guide during the screening process later. The criteria includes type of study,

publication date range, language of manuscripts, types of document and focus of the study. Both inclusion and exclusion criterion developed and chosen for the screening process were listed in Table 1 which includes literature type, publication date range, language and focus of the studies selected.

Table 1: Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Literature Type	• Journal Articles • Books • Case Study	• Conference Proceeding • News and Website Articles
Publication Date Range	• Year 2000 to 2020	• Before 2000
Language	• English	• Non-English
Focus of Study	• Banana Stem as Bio-adsorbent • Content of Banana Stem • Palm Oil Mill Effluent (POME)	• No relation to Banana Stem as Bio-adsorbent • No relation to Content of Banana Stem • No relation to Palm Oil Mill Effluent (POME)

2.5 Manuscript or Literature Collection

By using the keywords and the inclusion and exclusion criteria developed, literature were searched on the selected database. All literature that were considered as related to this study was collected and saved for further references. The meta-data of the literature collected was retrieved. The search results during this process were also saved for future references.

2.6 Screening of Collected Literature

Screening process were made based on the objectives of this study to prevent irrelevant data being analysed which can caused unreliability. The collected literature was screened and literature that contained data for banana stem content, banana stem as bio-adsorbent and adsorption capabilities of banana stem were analysed. The parameters analysed for the banana stem bio-adsorbent were removal of heavy metals, suspended solids, turbidity and chemical oxygen demand (COD) because all these parameters were important during the treatment of palm oil mill effluent (POME).

2.7 Data Analysis and Reporting

The data obtained from screened literature were extracted and analysed. Data obtained from various literature were compared. Based on the analysed data, discussion were made regarding the potential of banana stem as bio-adsorbent in palm oil mill effluent (POME) treatment. Recommendation for future study regarding this topic were also developed.

3. Results and Discussion

The study on the banana stem bio-adsorbent were made based on its capabilities to adsorb heavy metal ions, remove suspended solids and turbidity, and reduce chemical oxygen demand (COD) from the treated wastewater. Data from various researches were collected and analysed to show the potential of banana stem to be use in palm oil mill effluent (POME) treatment.

3.1 Removal of Heavy Metal Ions

The investigation was on the adsorption capabilities of banana stem were made to see whether banana stem are capable of removing heavy metal ions in wastewater. This is because in palm oil mill effluent (POME), there is existence of heavy metal ions such as zinc (Zn^{2+}), iron (Fe^{2+}) and copper

(Cu^{2+}) [7]. Data regarding the adsorption percentage of banana stem bio-adsorbent towards heavy metal ions were shown in Table 2.

Table 2: Adsorption percentage of banana stem bio-adsorbent towards heavy metal ions

References	Cd^{2+}	Cu^{2+}	Pb^{2+}	Fe^{2+}	Zn^{2+}
Yasim et al. (2016) [8]	-	83.00	95.00	-	91.00
Sheng et al. (2018) [9]	85.42	-	91.57	83.00	-
Sathasivam et al. (2010) [10]	89.70	86.20	-	89.00	81.60
Praveena et al. (2019) [11]	74.34	73.34	69.25	-	-

The banana stem bio-adsorbent were capable of adsorbing heavy metals ion that existed in palm oil mill effluent (POME) such as zinc (Zn^{2+}), iron (Fe^{2+}) and copper (Cu^{2+}) ions. The adsorption percentage were up to more than 73.34 % for copper ions, more than 83.00 % for iron ions and more than 81.60 % for zinc ions. The differences might be due to different for type of wastewater used which contains different concentrations of the particular heavy metal ions. Different working parameters such contact time and agitation speed can also effect the adsorption percentage. Banana stem from different species can also cause the differences.

In wastewater, microbial activity and biological wastewater process can be affected by high concentrations of heavy metals [12]. Removal of heavy metals from wastewater can also help to reduce the chemical oxygen demand (COD) value of the wastewater [13]. Previous study stated that as the heavy metals ion were remove from wastewater containing composite heavy metals, the chemical oxygen demand (COD) value reduction was estimated at around 87.90 % [14]. From this we can assume that banana stem bio-adsorbent might be suitable to be used in palm oil mill effluent (POME) treatment due to its ability to adsorb heavy metals that existed in palm oil mill effluent (POME).

3.2 Removal of Suspended Solids and Turbidity

The data regarding the capabilities of removing suspended solids and turbidity by banana stem bio-adsorbent from various study were analysed and compared to observe the banana stem adsorbing capabilities. The comparison between various previous researches for the adsorption of suspended solids and turbidity by banana stem bio-adsorbent were shown in Figure 2.

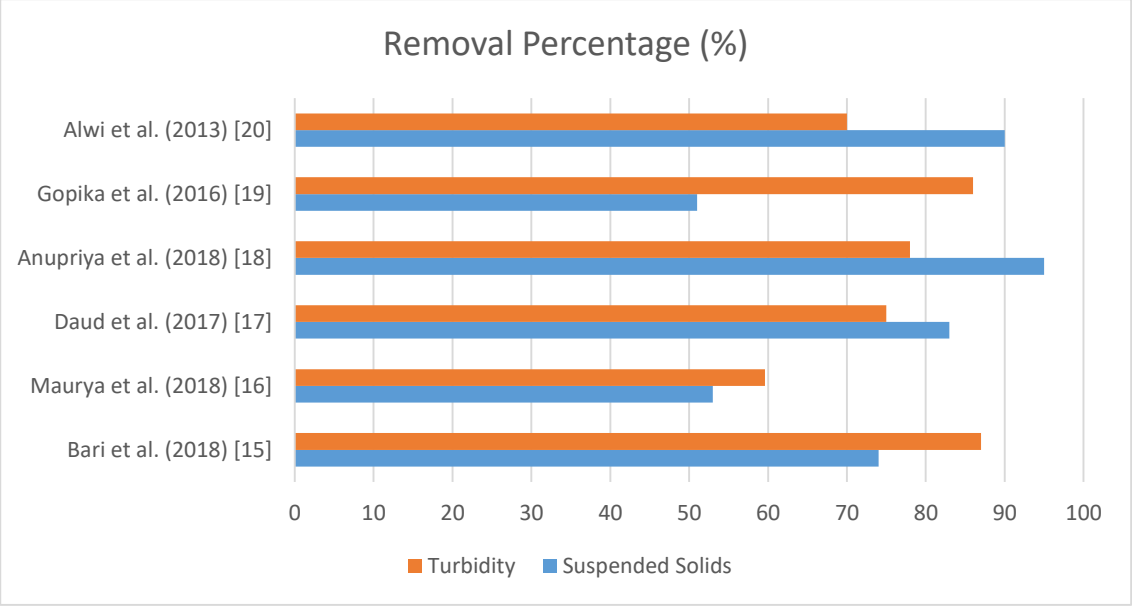

Figure 2: Comparison on Suspended Solids and Turbidity Removal by Banana Stem Bio-adsorbent

Based on the figure above, we can see that all studies shows that banana stem were able to remove more than 50.00 % of suspended solids in each of the wastewater sample used in each research. The removal of suspended solids can reach at almost up to 95.00 % in one of the study. As for turbidity, banana stem were able to reduce the turbidity value because banana stem adsorb smaller particles existing in the wastewater sample which are the main causes for turbidity [20]. As the banana stem adsorbs the smaller particles in the wastewater sample, the smaller particles will then settled down which will results in the reduction of turbidity value. So, we can say that the reduction in turbidity value were due to the smaller particles settling down which at the same time can also results in change in colour.

The differences in the adsorption percentage from the data collected can be caused by the type of wastewater itself. This is because the data were collected to show that the banana stem bio-adsorbent have the capabilities to adsorb suspended solids and reducing turbidity which can helps to improve the quality of the palm oil mill effluent (POME) when treated. So, different type wastewater have different amount of suspended solids and turbidity value which can affect the adsorption percentage of the banana stem bio-adsorbent. However, the capabilities of banana stem bio-adsorbent to adsorb suspended solids and reducing turbidity value can still be seen form the data collected.

During the adsorption process, pH value can cause difference in performance for the banana stem bio-adsorbent. Previous study shows that banana stem bio-adsorbent are able to remove highest percentage of suspended solids and turbidity at pH value in the range of 6 to 7. So we can assume that the banana stem bio-adsorbent are capable of adsorbing smaller particles to reduce the suspended solids and turbidity value near the neutral pH value. This might be due to the difference in electrostatic force of attraction between the adsorbent surfaces with the adsorbate caused by the difference in pH values. The banana stem bio-adsorbent can also interacts with the small particles existing in the wastewater through hydrogen bonding and also through hydrophobic-hydrophobic mechanism [13]. The removal percentage of suspended solids and turbidity at different pH values are shown in figure 3.

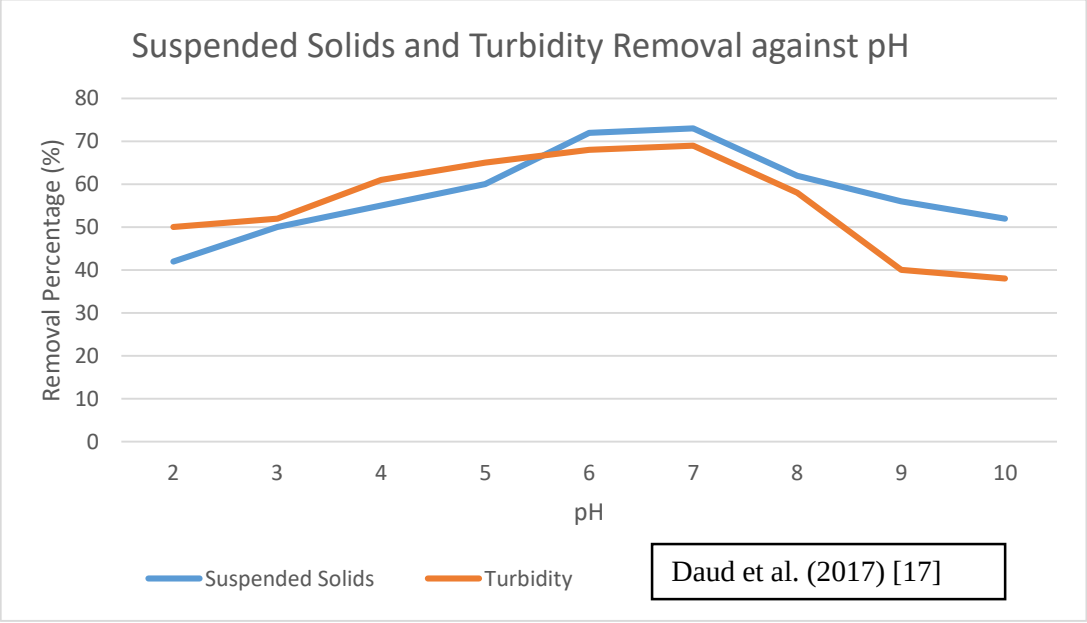

Figure 3: Comparison on Suspended Solids and Turbidity Removal with pH value

Banana stem contains polysaccharide compounds inulin. Inulin is a natural polymer which can caused bridging and entrapping of existing micro-floc to from a much larger floc [20]. By referring to the results obtained, all of them indicates that banana stem can be used as a natural coagulant for treatment process of water with high turbidity. There is high potential shown by banana stem to act as natural coagulant in water treatment process. Since the amount of suspended solids in palm oil mill

effluent (POME) were averaging at 18 000 mg/L [7] which can be considered as high, treatment with banana stem bio-adsorbent might reduce the suspended solids amount. Thus, this strengthen our assumptions which stated that banana stem bio-adsorbent can be suitable to be implemented in palm oil mill effluent (POME) treatment.

3.3 Reduction of Chemical Oxygen Demand (COD)

Previous studies that shows banana stem are capable of removing or reducing the chemical oxygen demand (COD) value of the wastewater treated with the banana stem. Data obtained from various literature regarding the removal of chemical oxygen demand (COD) for treatment with banana stem bio-adsorbent from previous study were shown in Figure 4.

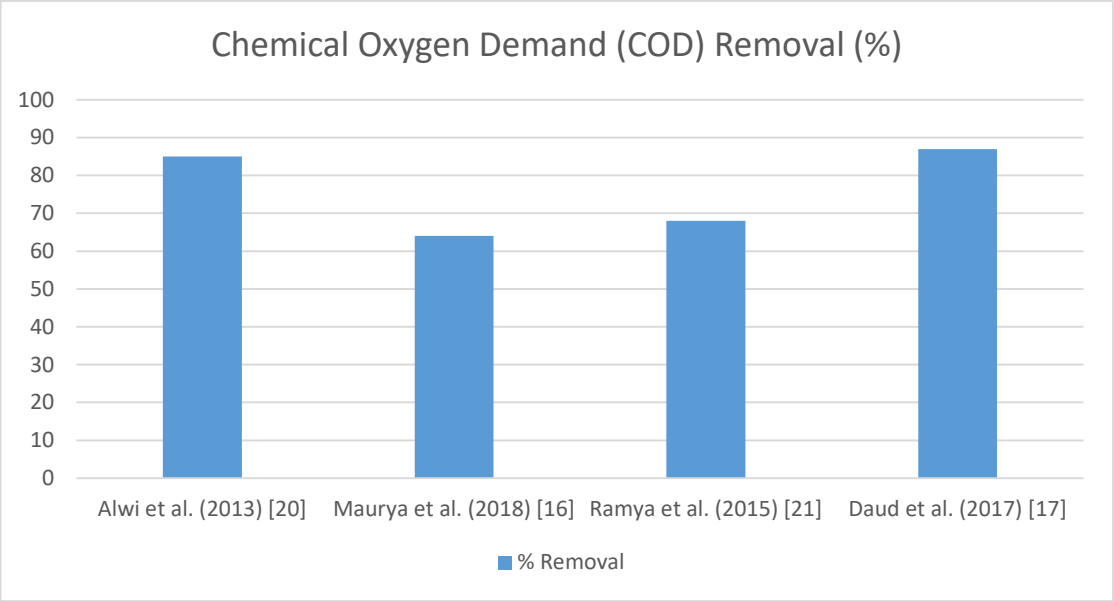

Figure 4: Comparison on Removal of Chemical Oxygen Demand (COD) by Banana Stem Bio-adsorbent

All for studies shows that treating wastewater with banana stem have positive effect towards the wastewater chemical oxygen demand (COD) value. Some of the studies even shows up to even more than 80.00 % chemical oxygen demand (COD) removal. However, in some of the studies, the wastewater final chemical oxygen demand (COD) value after treatment seems to be higher than the standards that have been set by the Department of Environment (DOE). Despite that, treatment with banana stem can still be implemented in pre-treatment process before the waste water undergoes further treatment prior to its discharge [11].

There are also previous study that shows functional groups existing in banana stem through Fourier Transform Infrared (FTIR) analysis. It was said that banana stem contains hydroxyl group (O-H), primary amine (N-H) and carboxylic acid group (-COOH) [22]. The existing functional groups in banana stem (hydroxyl and carboxylic acid groups) were said to be able to helps the banana stem adsorption towards organic pollutants and phenolic compounds [8] which can reduce chemical oxygen demand (COD) value. This can also make banana stem bio-adsorbent a suitable in palm oil mill effluent (POME) treatment because palm oil mill effluent (POME) contains certain powerful water-soluble antioxidants phenolic compounds flavonoids [23].

The parameters or conditions for the treatment such as pH value, contact time and dosage can also plays a role regarding the banana stem bio-adsorbent performance. The performance of banana stem bio-adsorbent to remove chemical oxygen demand (COD) can be assume to perform at its best at pH value in the range of 6 to 8. This was shown in the Figure 5 where it shows that the chemical oxygen

demand percentage removal are at the highest value when the pH are at 6 and 8. So, we can assume that banana stem bio-adsorbent perform best near neutral range of pH value.

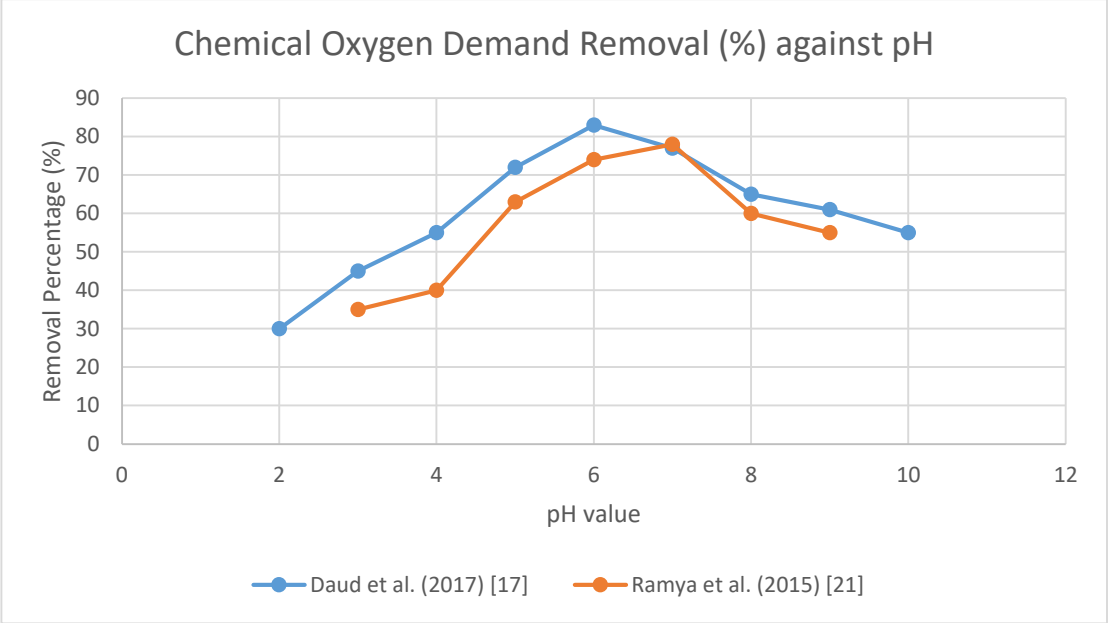

Figure 5: Graph for Chemical Oxygen Demand Percentage Removal against pH

Next conditions or parameters that can affect the adsorbing capabilities of banana stem bio-adsorbent is contact time between the bio-adsorbent and the wastewater or adsorbate. Generally, higher contact time between adsorbent and adsorbate will results in higher removal percentage. However, at a certain point or duration for contact time, the removal percentage will reach a constant value, which indicates that it has reach the maximum removal percentage where further or longer contact time won't affect the removal percentage value. Based on previous study, the removal percentage of chemical oxygen demand (COD) increase as contact time increase, but as the contact time reaches 150 to 180 minutes, the removal percentage of chemical oxygen demand (COD) reaches the highest value. Contact time longer than 150 to 180 minutes shows no increase regarding the removal percentage of chemical oxygen demand (COD). During the early stage of contact time, the adsorption process appears to occur at a rapid rate because the numbers of available sites are much larger than the number of adsorbate species to be adsorbed. However, as the contact time increase, the adsorption rate slows down because the available sites for adsorption becomes lower and eventually all the adsorption sites will be fully occupied by the adsorbate causing the removal percentage to become constant at a certain point of contact time. The comparison for contact time against removal percentage of chemical oxygen demand (COD) was shown in Figure 6.

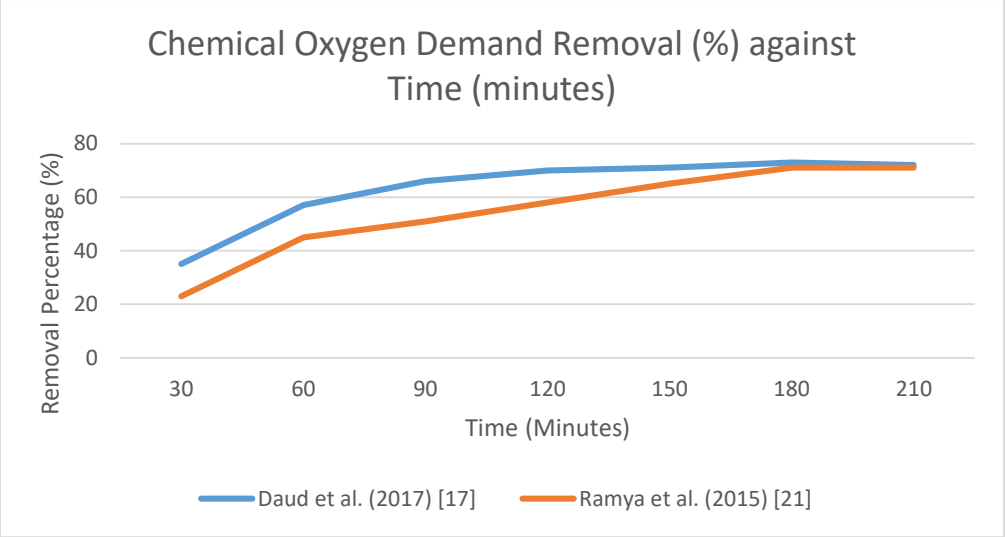

Figure 6: Graph for Chemical Oxygen Demand Percentage Removal against Time

Agitation speed can also affect the performance of banana stem as bio-adsorbent in removing or reducing chemical oxygen demand (COD) value. Based on the data obtained from previous study shown in Figure 7, the chemical oxygen demand (COD) removal percentage were highest when the agitation speed was at the range of 125 RPM and 150 RPM. When the agitation speed exceeds the range of 125 RPM and 150 RPM, the removal percentage of chemical oxygen demand (COD) by the banana stem bio-adsorbent starts to drop from its highest value. This might be due to desorption process at the equilibrium time that occurs at higher agitation speed. Thus, when desorption occurs, the adsorbate that have been adsorb will be release back into the wastewater sample causing the removal percentage to drop. Therefore, the difference in agitation speed can cause kinetics of the adsorption to change, as well as the equilibrium adsorption capacity [24]. So, we can assume that the optimum agitation speed for banana stem bio-adsorbent is at around 125 RPM to 150 RPM.

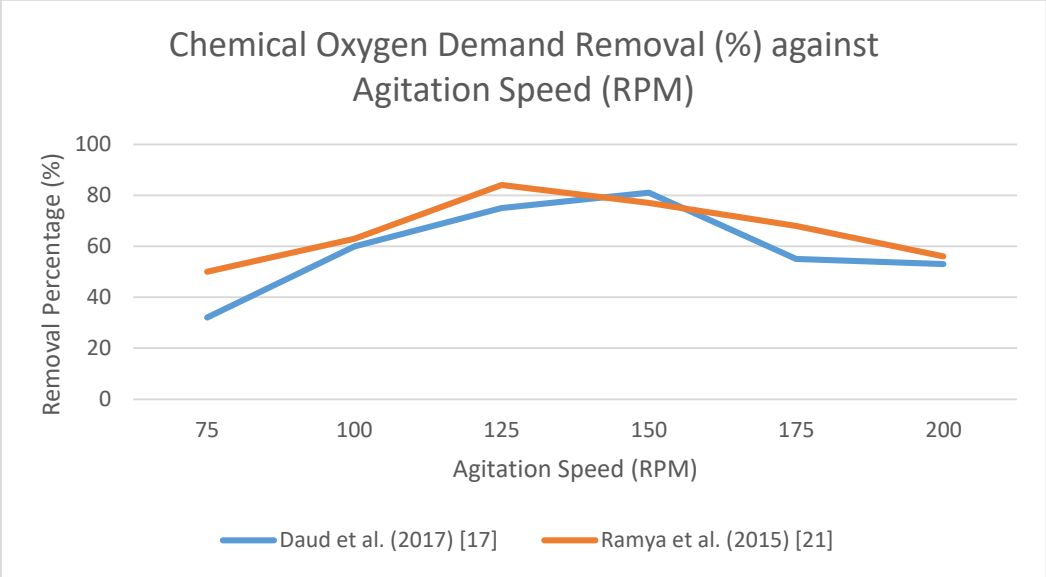

Figure 7: Graph for Chemical Oxygen Demand Percentage Removal against Agitation Speed

By taking account of the abilities to lower the chemical oxygen demand (COD) of bio-adsorbents from banana stem, we can say that the usage of banana stem as bio-adsorbents can be applied for palm oil mill effluent (POME) treatment. This is because the chemical oxygen demand (COD) value of palm oil mill effluent (POME) was very high ranging at around 15 000 to 100 000 mg per litre and the average

chemical oxygen demand (COD) value was at around 51 000 mg per litre [7]. So it is important to reduce the chemical oxygen demand (COD) value of palm oil mill effluent (POME). Due to this, banana stem can be considered to have the potential to be implemented in palm oil mill effluent (POME) treatment because the banana stem bio-adsorbents were capable of reducing chemical oxygen demand (COD) value which are very important in palm oil mill effluent (POME) treatment. As for the process conditions, the optimum pH value range for the banana stem bio-adsorbent are from 6 to 8. The optimum contact time between the banana stems bio-adsorbent and the wastewater is at around 150 to 180 minutes with the agitation speed between 125 RPM and 150 RPM.

4. Conclusion

Based on the data obtained from various research, we can assume that banana stem bio-adsorbent have a promising potential as bio-adsorbent to be use in palm oil mill effluent (POME) treatment. The potential of banana stem as bio-adsorbent was shown through its capabilities to adsorb heavy metal ions, removing suspended solids and turbidity, and removing chemical oxygen demand (COD) of wastewater. All of these parameters are among the concerned parameters in palm oil mill effluent (POME) treatment. So by having the ability to improve those parameters in wastewater, shows that banana stem might have the potential to be used in palm oil mill effluent (POME) treatment.

Banana stem bio-adsorbent was found capable of removing heavy metal ions such as zinc ion, copper ion and iron ion which exists in palm oil mill effluent (POME). Banana stem bio-adsorbent also capable of removing more than 50.00 % of suspended solids in wastewater according to various studies. Chemical oxygen demand (COD) value of the wastewater can also be reduced up to more than 64.00 % through treatment with banana stem bio-adsorbent.

Previous study also shows that banana stem bio-adsorbent performance can be affected by the surrounding process conditions such as pH value, contact time and agitation speed. Based on the data collected, banana stem bio-adsorbent works best at near neutral range of pH value. As for the contact time, 150 minutes to 180 minutes can be estimated as the optimum contact time between the bio-adsorbent and the adsorbate. Agitation speed ranging from 125 RPM to 150 RPM can be assumed as the optimum agitation speed during treatment with banana stem bio-adsorbent since previous study stated that agitation speed at around 125 RPM to 150 RPM results in the highest removal percentage of chemical oxygen demand (COD).

Supporting data such as the banana stem content and functional group existing in banana stem that can contributes towards the adsorbing capabilities were also shown. Banana stem contains cellulose, hemi-cellulose and lignin which can helps in adsorbing phenolic compounds and soluble organic pollutants. Due to this, the chemical oxygen demand (COD) value of the treated wastewater can be reduce. Functional groups such as hydroxyl (O-H) and carboxylic acid (-COOH) can also help heavy metal ions and phenolic compounds adsorption.

Thus, we can assume that banana stem bio-adsorbent are viable to be use in palm oil mill effluent (POME) treatment.

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