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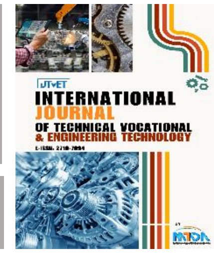

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Palm Oil Mill Effluent (POME) Pretreatment Using Tapioca Starch as A Coagulant

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ABSTRACT
Palm oil mill effluent (POME) is a wastewater generated from the processing of crude palm oil. It is a by-product of the extraction process and is a mixture of water, oil, and residual solids. It is a brownish liquid waste that has high levels of turbidity, total dissolved solids, chemical oxygen demand (COD), and other contaminants. This paper reports a study of POME coagulation and flocculation with natural coagulant. Tapioca starch was utilized to investigate its potential as a coagulant for the removal of selected contaminants namely pH, chemical oxygen demand (COD) turbidity and total dissolved solid (TDS) in POME for various anaerobic ponds. The experimental investigation involved batch coagulation tests using different concentrations of tapioca starch. The coagulation efficiency was evaluated based on the removal of suspended solids, chemical oxygen demand (COD), and turbidity from POME samples. Additionally, the optimum dosage of tapioca starch was determined through a series of jar tests. As a result, the percentage of COD, turbidity, and total solids removal from the sample by coagulation were 26.7%, 62.8.9% and 40.8% respectively for Anaerobic Pond 1. Anaerobic Pond 2 showed results of 4.02%, 20.9% and 31.1 % while Anaerobic Pond 3 removed about 24.9%, 62.9% and 0.2% of COD, turbidity and total solids dissolve correspondingly. In conclusion, this research demonstrates the potential of tapioca starch as an effective coagulant for POME pretreatment. The findings provide valuable insights into the development of sustainable and environmentally friendly approaches for managing POME. The utilization of tapioca starch as a coagulant in POME pretreatment could contribute to the reduction of pollution load and facilitate the implementation of efficient treatment strategies in the palm oil industry.

1.0. Introduction

Water, being the most crucial component of all natural resources, poses significant challenges for the water industry due to the presence of natural organic matter. This organic matter not only increases the chemical demand but also diminishes disinfection residuals while promoting microbial growth in distribution systems (Nath et al., 2019). Furthermore, it can lead to water discoloration and excessive chemical requirements. To address these issues, water treatment processes such as coagulation, sedimentation, filtration, and disinfection are commonly employed. However, the lack of accessible and affordable water treatment systems in rural or underdeveloped regions necessitates the utilization of straightforward and reasonably priced point-of-use technologies like coagulants.

In Malaysia, the oil palm industry generates a substantial amount of agricultural waste, specifically palm oil mill effluent (POME). POME, a thick and viscous liquid waste, possesses a brownish colour and emits an unpleasant odour. It also contains soluble components that can be detrimental to the environment. Various alternative treatment methods have been explored to manage POME, including soil application, membrane technology, electrocoagulation, flotation, adsorption, coagulation, and flocculation. Coagulation and flocculation are widely utilized in the treatment of both water and wastewater and are considered conventional methods. These processes involve straightforward procedures.

A crucial element in determining the efficiency of this system is the choice of coagulant. Coagulants can be categorized into chemical coagulants, derived from chemical substances and commercially available options such as alum, polyaluminium chloride, polyferric chloride, and ferric chloride, and natural coagulants (Mohd Zin Nur & Mohd Omar, 2017; Shaylinda et al., 2019).

Enhanced chemical coagulants offer improved efficiency in removing organic load, while mitigating some of the drawbacks associated with traditional methods. These advanced coagulants reduce the dosage requirements, resulting in lesser sludge generation. By utilizing these improved coagulants, the treatment process becomes more sustainable and cost-effective. Moreover, the use of enhanced chemical coagulants addresses concerns regarding heavy metal concentrations in the effluent. Innovative formulations minimize the presence of heavy metals like aluminium, thereby reducing their potential impact on human health and the environment (Choong Lek et al., 2018).

In the past few years, there has been an increasing focus on employing natural coagulants in wastewater treatment due to their environmentally friendly characteristics and potential cost-effectiveness. Tapioca starch, derived from the cassava plant, has gained significant attention as a promising coagulant for diverse industrial effluents, particularly those with high levels of organic matter.

The primary objective of this study is to assess the viability of tapioca starch as a natural coagulant for removing selected contaminants, including pH, chemical oxygen demand (COD), turbidity, and total dissolved solids (TDS), from various anaerobic ponds containing POME.

2.0. Literature review

2.1. Palm oil mill effluent (POME)

Large amounts of waste and byproducts are created during the manufacture of crude palm oil. Empty fruit bunches (EFB), mesocarp fruit fibres (MF), and palm kernel shells make up the solid waste streams (PKS). Often viewed as a significant environmental problem, POME, or Palm Oil Mill Effluent, is an underutilised liquid waste stream from palm oil mills that is produced during the palm oil extraction/decanting process. However, it is an excellent source for the synthesis of biomethane. As a result, several countries that produce palm oil have stricter rules regarding the release of POME. The waste from palm oil mills is a colloidal solution made up of 2-4% suspended solids, 4-5% total solids, and 95–96% water. It also contains 0.6-0.7% oil. The typical range of the biological oxygen demand (BOD) is between 25,000 to 65,714 mg/L (Hasanudin et al., 2015).

2.2. Natural coagulant

2.2.1. Tapioca starch

Tapioca is scientifically known as Cassava (Manihotesculenta Crantz) and commonly grown in Asia, South America and Africa. Starch can be applied as a coagulant or flocculant by using its natural form or modified from. Starch destabilizes colloid through bridging mechanism (N. Shaylinda et al., 2016). The effectiveness of cassava peels as a coagulant is attributed to their molecular structure, which contains large functional groups that possess a strong affinity for coagulating with elements and impurities present in water. Additionally, cassava starch granules consist of amylose (20%) and amylopectin (80%) (Adetan et al., 2003). As a result, the sludge generated during the coagulation process using plant-based coagulants, such as cassava, offers cost-effective and highly biodegradable properties. Furthermore, these coagulants are non-toxic, non-corrosive, and unlikely to cause extreme pH levels in water. Moreover, natural coagulants are relatively inexpensive and readily available locally.

2.2.2. Coagulation and Flocculation

Coagulation and flocculation are two common treatment methods used in the water treatment industry to clean and increase the effectiveness of wastewater treatment. In essence, coagulation and flocculation involve adding substances known as coagulants to wastewater to aid in the flocculation of small and fine particles into larger particles that will eventually settle. A coagulant diminishes the repelling forces among particles, enabling them to aggregate and precipitate from the liquid. In contrast, flocculants amplify the interaction and adhesion between already coalesced particles, facilitating the creation of more substantial and denser flocs, which can be more readily isolated from the liquid matrix. Currently, polyaluminum chloride (PACl), polyaluminum ferric chloride (PAFCl), polyferrous sulphate (PFS), polyferric chloride (PFCl), and other coagulants are used in the coagulation and flocculation process. It has been demonstrated that these synthetic coagulants are highly effective and are recommended for use with wastewater. There are various alternative coagulants generated from natural resources that can potentially be utilised for wastewater treatment. Due to their eco-friendly qualities, these coagulants, known as natural coagulants, are encouraged to be utilised.

3.0. Methodology

3.1. Palm Oil Mill Effluent (POME)

POME samples were collected from Kilang Kelapa Sawit Pagoh, Sime Darby Plantation Johor, Malaysia. These samples were obtained from three different ponds: anaerobic pond 1, anaerobic pond 2, and anaerobic pond 3. These specific ponds were selected based on the presence of organic matter and suspended solids. To ensure preservation, the samples were placed in airtight chemical containers and stored in a dry area within the laboratory. Thick black plastic bags were used to cover the samples, preventing exposure to sunlight and minimizing microbial decomposition. It should be noted that the properties of POME samples can vary from batch to batch due to different species and age factors (Yacob et al., 2006). Additionally, the processing parameters for Crude Palm Oil (CPO) production can also impact the properties of POME (Ahmad et al., 2009). The initial characteristics of the collected POME samples, as determined through laboratory testing are;

Table 1.1: Initial characteristics of POME

PARAMETER	ANAEROBIC POND 1	ANAEROBIC POND 2	ANAEROBIC POND 3
pH	8.96	9.16	9.21
Turbidity (NTU)	269	541	540
COD (mg/L)	750	657	467
TDS (ppm)	1660	1566	1509

3.2. Preparation of Tapioca Starch

3.2.1. Tapioca powder

Tapioca was collected from a local market in Pagoh, Johor. Tapioca is washed using tap water and peeled the brownish outer layer, leaving only the white flesh. Cut down the tapioca white flesh into smaller sizes and blend with a ratio 1:1 to distilled water as in Figure 1.1. After the blending process, the mashed white flesh was left to rest and settling for 5 hours minimum. The excess distilled water was removed by filtration process of the white flesh solution using muslin cloth, a filter tunnel, and a conical flask. Last step in the preparation of the tapioca powder was the drying of the solution by spreading it onto a tray, and let it parch by sun- dried.

Figure 1.1: Preparation of Tapioca Powder

3.2.2. Tapioca starch preparation

The tapioca powders dissolved in distilled water. Then, heated until it was in gelatinized form as in Figure 1.2. The gelatinized solution was allowed to rest at room temperature. Afterward, stored in a refrigerator, before it is ready to be used.

Figure 1.2: Gelatinized Form of Tapioca starch

3.3. Equipment and method

3.3.1. Coagulation-flocculation process

The sample is examined using the Jar test method, which is then used to determine how long it will take for the particles to coagulate. Jar tests were performed using flocculator (VELP Scientifica) to simulate the POME treatment coagulation – flocculation process. Coagulant dosage ratio tapioca to alum is shown in Table 1.2. Approximately 300 mL of POME was contained in 500 mL beaker for each run of experiment. For each POME sample, there was quick mixing at 200 rpm for 4 minutes, slow mixing at 30 rpm for 15 minutes, and settling for 30 minutes on 800 ml of POME sample as in Figure 1.3. The treated POME in each beaker was allowed to settle for a duration of 4 h. After 4 h, top of the beaker would form a supernatant layer while sludge will settle at the bottom of the beaker. The supernatant layer was extracted for COD, TDS and turbidity test.

Table 1.2: Coagulant dosage set

No.	Coagulant	Dosage
1	Alum	2 g
2	Starch	10 g
3	Alum + starch	2 g + 10 g
4	Alum + starch	10 g + 2 g

Figure 1.3: Jar Test Untreated POME

Figure 1.4: Treated POME with dosage set for anaerobic pond 1

Figure 1.5: Treated POME with dosage set for anaerobic pond 2

Figure 1.6: Treated POME with dosage set for anaerobic pond 3

3.4. Chemical analysis

The effectiveness of tapioca starch in the treatment of POME was evaluated by calculating the overall removal percentages of TDS, turbidity, and COD, as indicated by Equation [1], utilizing the instrument depicted in Figure 1.7.

$$\boldsymbol{Removal\ percentage}\ \% = \frac{\boldsymbol{Initial\ reading - Final\ reading}}{\boldsymbol{Initial\ reading}} \qquad \textbf{............. [1]}$$

Figure 1.7: Instrument for COD, pH and turbidity respectively

4.0. Discussion of analysis and findings

4.1. Result of treated POME

Table 1.3: Result of Treated POME Based on Dosage Set of Coagulants

Paramater	Anaerobic pond	Dosage set			
		Alum	Tapioca starch	Alum + tapioca (2g + 10g)	Alum + tapioca (10g + 2g)
pH					
	1	7.01	8.75	7.97	4.55
	2	6.89	8.70	7.66	5.09
	3	6.86	8.62	7.95	4.55
Turbidity					
	1	675 (Increased 15%)	444 (Increased by 6%)	412 (Increased by 5%)	950 (Increased by 25%)
	2	640 (Increased by 2%)	453 (17%)	511 (5%)	850 (Increased by 57%)
	3	505 (6%)	464 (14%)	558 (Increased by 3%)	785 (Increased by 45%)
COD					
	1	202 (87%)	1217 (26%)	1390 (16%)	1174 (29%)
	2	299 (81%)	1503 (4%)	473 (69%)	1560 (0.4%)
	3	418 (72%)	1133 (24%)	347 (43%)	1349 (10%)

Table 1.3 shows that tapioca starch in the case as single coagulant provides low removal of turbidity. Because the low removal of turbidity is caused by the alkaline POME. (Mohd Zin Nur & Mohd Omar, 2017) , stated the starch coagulant seems to be more efficient in acidic condition. According to

Choong Lek et al. (2018), the efficiency of turbidity removal increased as the pH level rose from 4 to 6.5 but then exhibited a significant decrease until reaching pH 8. In terms of COD removal, the use of tapioca starch as a single coagulant resulted in minimal removal. Moreover, the pH range of 4 to 6 had little impact on COD removal efficiency, but there was a decline in efficiency between pH 6 and 8. However, when combined with alum (at a dosage of 2g alum + 10g tapioca starch), reliable COD removal was achieved.

5.0. Conclusion and future research

This study showed that tapioca starch is a viable and cheap alternative to replace synthetic inorganic coagulants and flocculants for the treatment of POME. While the removal of the turbidity and COD are slightly removal, the improvement can be made by adjusting the pH of POME. The coagulation performance of tapioca starch can be optimized by adjusting the pH of the water or wastewater being treated. Next is using coagulant aids or additives to enhance the performance of tapioca starch as a coagulant. Common coagulant aids include inorganic salts namely alum, ferric chloride, or synthetic polymers. These additives can improve flocculation formation, settleability, and enhance the overall coagulation efficiency. Pre-treatment techniques also enhance the efficiency of tapioca starch as coagulant. For example, enzymatic hydrolysis or modification of tapioca starch can improve its molecular weight and structure, leading to enhanced coagulation performance. Lastly is dosage optimization. By adjusting the dosage can help improve coagulation performance and minimize excessive coagulant usage. While the practical utility of natural coagulants for real-world challenges remains unclear and the comparative advantages of natural coagulants over conventional counterparts are yet to be validated, various experimental studies have showcased encouraging avenues for enhancing natural coagulants. These encompass ideas like multifunctionality, amalgamation with other coagulant variants, chemical modification to optimize efficacy, and integration with complementary treatment methodologies. Through a deeper comprehension of its efficacy and the contemplation of potential applications, this research strives to foster sustainable practices within the palm oil industry, all while mitigating its ecological impact. In conclusion, exploring the application of tapioca starch as a coagulant for POME pretreatment presents an opportunity to address the environmental challenges associated with palm oil production.

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